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Stimulation of Yield in
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STIMULATION OF YIELD IN HEVEA BRASILIENSIS I. PREWAR EXPERIMENTS WITH VEGETABLE OILS

By

E.D.C. BAPTIST

A brief historical review is given of methods used for stimulating the latex yield of rubber trees and experiments are described in which vegetable oils applied to lightly scraped bark below the tapping cut resulted in large increases in yield. The results of these early experiments provided a clear picture of the reaction of the tree to yield stimulation and led to the development and commercial use of yield stimulants.

The practice of scraping the bark of rubber trees below the tapping cut which is common on many estates and holdings, ostensibly for tapping hygiene, may have been prompted by a belief that the operation increases the yield of latex.

Methods of artificially stimulating the yield of hevea have been tried at various times. A German chemist, P.S. KAMERUN (1912) as early as 1912 patented a method to increase the yield of hevea trees by scraping off periodically the outer dead layers of bark along the whole tapping panel from the ground to the highest level of the tapped area. The patent was not accepted in Malaya. A former Director of Agriculture in Samoa, Dr E. Fickendey (SHARPLES 1918), applied in 1918 for patent rights for a method of scraping away the outer corky bark below the tapping cut which exposed the cork cambium and for which he claimed an increase in yield of about 50 per cent.

Experiments were carried out under the aegis of the Rubber Research Institute of Malaya on a number of estates during the period 1929 to 1930 (See Annual Reports pages 19 and 16 respectively) with bark scraping and application of nitrate of soda, wood ash, cattle manure and an increase in yield was recorded.

About this time a preparation called Neubark, marketed by Parry Davis, consisting of a mixture of cattle manure and clay with minor ingredients which included sulphate of iron and permanganate of potash, claimed to be yield stimulants, was put on the market. The preparation was applied to scraped bark along a six inch strip below the tapping cut and was claimed to result in a marked increase in the yield of latex.

Neubark was soon superseded by another preparation named Solar Vim which was marketed by the Singapore Fertiliser and Chemical Works and described as a 'radiant heat tree vaccine' and 'living cell stimulator' for rubber trees. Solar Vim was manufactured in brick form and required to be made into a paste

before application to the bark above and below the tapping cut. It was claimed to be an improvement on Neubark but from all accounts appeared to be substantially the same. The manufacturers advised that trees treated with Solar Vim be manured with their organic fertiliser sold under the trade name 'Fertilite' in order to keep up the dry rubber content of the latex.

Work on stimulation of bark renewal was undertaken at the Rubber Research Institute of Malaya in 1937 (BAPTIST, 1939; BEELEY and BAPTIST, 1939) and it was shown that the rate of bark renewal during the first year was significantly increased by commercial palm oil applied to renewing bark above the tapping cut. This effect was ascribed by Baptist to the presence of natural hormones present in physiological concentrations in the palm oil rather than to the physical effects of the oil coating.

It was with the intention of distinguishing between these two possible effects that in 1939 an experiment was set up on buddings of four clones with treatments consisting of red palm oil, bleached palm oil and liquid paraffin. The records of this experiment were unfortunately lost during the Japanese occupation of Malaya.

Indolyl-acetic acid at concentrations of 20, 200 and 1,000 parts per million in lanolin applied to the tapping panel and directly on the cambium after stripping the bark, failed to have a measurable effect on the rate of bark renewal (Baptist 1939).

The work on stimulation of bark renewal led to the investigation of the effect on latex yield of palm oil applied to the bark below the tapping cut and in a preliminary experiment carried out in 1939/1940 it was shown that yield was significantly increased by application of palm oil to lightly scraped bark below the tapping cut.

EXPERIMENTAL

Suitably designed experiments were set up during 1941 on two estates to verify the results of the preliminary experiment, and are described in the Rubber Research Institute of Malaya Report for the Period January 1941 to August 1945 on page 28. In these experiments light scraping (grooming) of the bark consisted of the removal of the outer layers of cork to a distance of twelve inches below the tapping cut, and heavy scraping the removal of the outer cortical layers and the stone cell ring resulting in a copious exudation of latex.

Preliminary yields were measured on three consecutive tapping days before the treatments were applied. The yield from each experimental block was recorded separately at weekly intervals during the first month and at fortnightly intervals thereafter.

The experiment on estate *A* situated on an inland alluvial soil, was of a simple randomized block design with six replications of each treatment and was set up on old seedling rubber trees planted in 1906. The treatments consisted of light scraping and of no scraping, with and without one application of red palm oil

or linseed oil. The latex yield from each plot, diluted with water, was coagulated in the tapper's bucket by addition of acetic acid and the coagulum was made into crepe, dried and weighed. The results are presented in TABLE I and are shown graphically in *Figure 1.*

TABLE I: MEAN YIELDS IN GRAMS PER TREE FOR A PERIOD OF FIFTYNINE TAPPING DAYS ADJUSTED BY REGRESSION ON PRELIMINARY YIELDS

Treatment	*No oil*	*Palm oil*	*Linseed oil*	*Difference due to* palm oil	linseed oil
Light scraping	1,444	1,571	1,499	+ 127	+ 55
No scraping	1,078	1,276	1,269	+ 198	+ 191
Difference	+ 366	+ 295	+ 230		
Standard error of a treatment mean ±61.2					

The experiment on estate *B*, situated on a coastal alluvial clay with peat soil, was a factorial experiment, 3 × 2 × 2 with interactions partially confounded and balanced, on three tapping tasks of old seedling rubber trees planted in 1919 and yielding over 400 lb per acre per year. The treatments consisted of light scraping, heavy scraping and no scraping with and without one application of palm oil to one foot of bark below the tapping cut, and one application of palm oil at fortnightly intervals to recently tapped bark above the cut.

The latex yield from each plot was weighed to the nearest half ounce and after a thorough stirring a volume of 100 millilitres was measured out in small aluminium pans where it was coagulated. The coagulum was rolled thin, dried, weighed to the nearest gram and the total yield of dry rubber per plot was calculated. The results are presented in TABLE II and are shown graphically in *Figure 2.*

TABLE II: MEAN YIELDS IN GRAMS PER TREE FOR A PERIOD OF SIXTYEIGHT DAYS ADJUSTED BY REGRESSION ON PRELIMINARY YIELDS

Treatment	*No oil*	*Palm oil*	*Difference due to oil*
No scraping	768	976	+ 208
Light scraping	1,513	1,739	+ 226
Heavy scraping	590	584	− 6
Difference due to:			
Light scraping	+ 745	+ 763	
Heavy scraping	− 178	− 392	
Standard error of a treatment mean ±77.03			

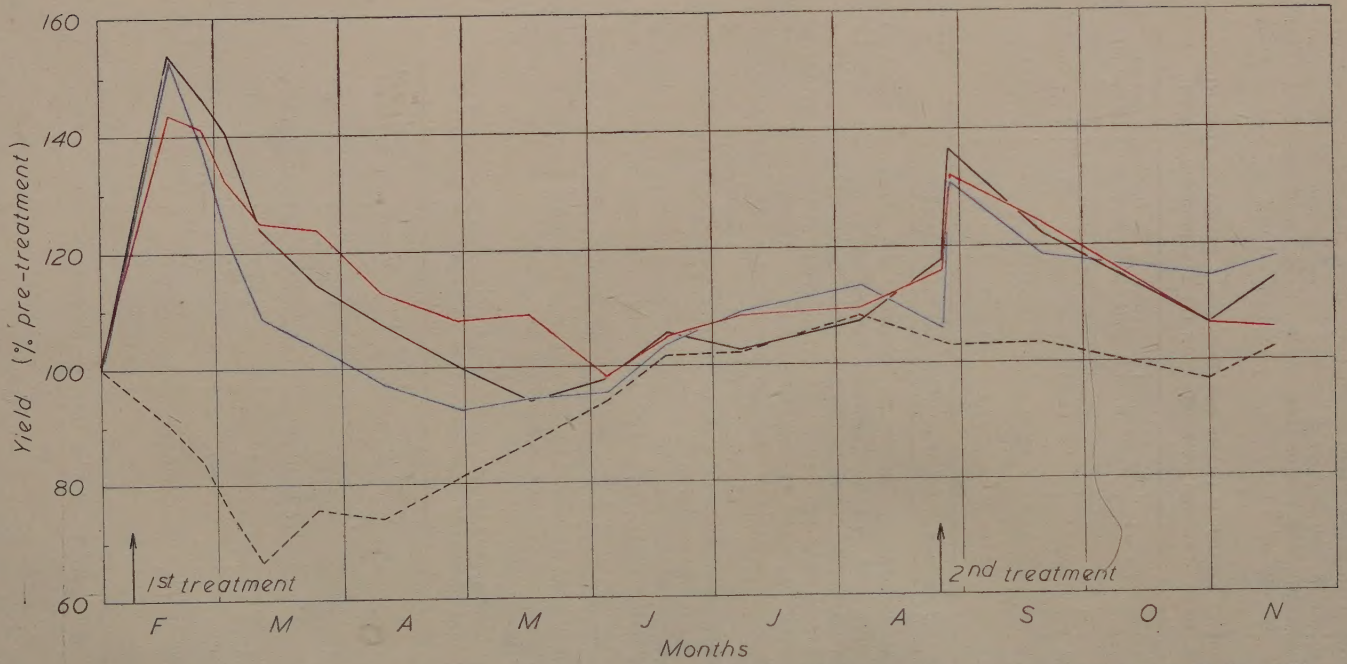

Figure 1. Slaughter tapping experiment with and without yield stimulant. Yields are expressed as a percentage of the yield before treatment.

Scraping and linseed oil

Scraping and palm oil

Light scraping

Control (no treatment)

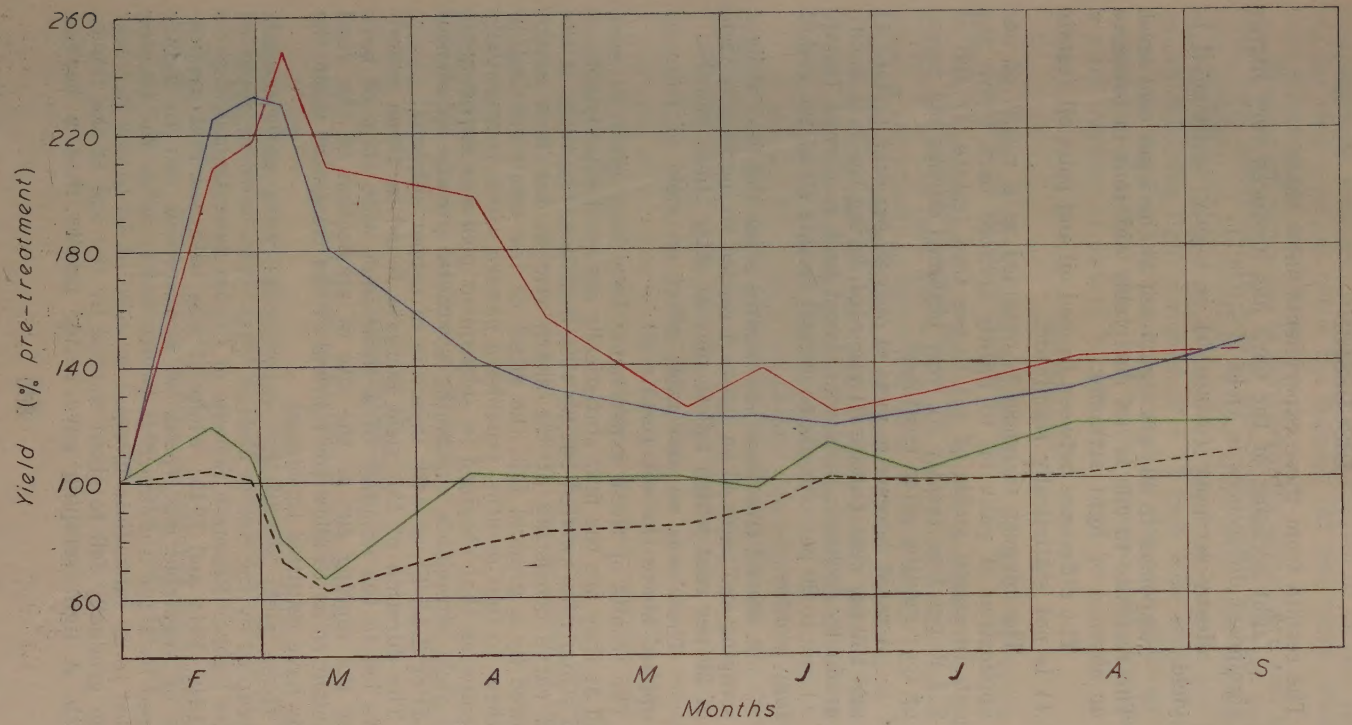

Figure 2. Yield stimulation experiment at estate B on coastal clay soil with peat. Yields are expressed as a percentage of the yield before treatment.

..... *Control (no treatment)*

——— *Light scraping*

——— *Palm oil alone*

——— *Scraping and palm oil*

DISCUSSION

The results from these experiments show that:

Light scraping of the bark has produced very highly significant differences in yield ($P<0.001$).

Heavy scraping (estate *B*) is highly detrimental to yield.

Responses to oils are significant at the 5 per cent level. The response to oils is not detectably different in presence or absence of light scraping.

The difference between linseed oil and palm oil (estate *A*) is not statistically significant.

The biggest response is obtained as a result of one application of palm oil to lightly scraped bark below the cut. Increased yields of 1.1 lb per tree (estate *A*) and of 2.1 lb per tree (estate *B*) were obtained during the period of four months after treatment.

A rapid increase in yield of over 80 per cent (estate *A*) and 150 per cent (estate *B*) recorded during the first month gradually declined; yield was almost back to normal (estate *A*) and to 20 per cent above normal (estate *B*) at the end of four months.

A second treatment six months after the first of light scraping and palm oil on estate *A* caused an increase in yield of 30 per cent which fell to normal after three months.

There was no detectable effect on yield of palm oil applied above the cut (estate *B*).

The results of these experiments have been given in some detail as they are the first statistically designed experiments on yield stimulation carried out by this Institute. The form of the yield curve consisting of the sharp rise in the first month followed by a gradual fall, the effect of the treatment lasting for three to four months, provides a picture which is essentially the same as that obtained in subsequent post-war experiments with yield stimulants containing synthetic growth substances (2,4-D or 2,4,5-T) or with injection of copper sulphate.

The duration of the yield increase found in these experiments led to the adoption of a three inch wide strip of bark below the tapping cut as the site of application of the yield stimulant so as to allow for renewal of the treatment when the yields have returned to normal.

These yield stimulation experiments were unfortunately interrupted by the war in Malaya. They were, however, repeated at the Rubber Research Scheme of Ceylon (see Annual Reports for 1942, 1944 and 1945) where it was observed that applications of vegetable oils (palm oil and coconut oil) to lightly scraped bark for a distance of twelve inches below the tapping cut led to an immediate increase in yield of 70 to 100 per cent which gradually fell to about normal by the end of the fourth month. A light scraping gave better results than a heavier

scraping both with and without the application of oil and scraping for twelve inches below the tapping cut was more effective than scraping for six inches.

These high responses to light scraping alone have not, however, been confirmed in a post-war experiment carried out at this Institute on old seedling rubber trees with thin corrugated renewed bark. In this experiment the yield increase in the first month following light scraping of a 12 inch wide strip of bark below the tapping cut did not exceed 20 per cent although the application of a yield stimulant to the scraped bark resulted in a yield increase of almost 90 per cent.

SUMMARY

Methods of artificially stimulating the yield of hevea are reviewed.

Two experiments are described and it is shown that a light scraping of the bark for a distance of twelve inches below the tapping cut results in large increases in yield which are further enhanced by the application of palm oil to the scraped bark.

The response to treatment is very rapid, peak yields are obtained in the first month and these gradually return to normal over a period of three to four months.

A smaller but highly significant response was obtained as a result of a second application of the treatment six months after the first.

I have to record my indebtedness and thanks to Messrs E.M. Stewart and A.G. Barron-Toop, the Managers of estates on which the experiments were carried out, for their generous cooperation and to my field assistant, Mr M.I. Nayar, for the competent recording and summarising of yield records.

I am also indebted to Mr H. Fairfield Smith, formerly Statistician of the Rubber Research Institute of Malaya, for the statistical analysis of the yield data.

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March 1955

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STIMULATION OF YIELD IN HEVEA BRASILIENSIS
II. EFFECT OF SYNTHETIC GROWTH SUBSTANCES ON YIELD AND ON BARK RENEWAL

By

E.D.C. BAPTIST AND P. DE JONGE

Application to lightly scraped bark below the tapping cut of a number of synthetic growth substances in an oil vehicle has resulted in increases in yield and in the thickness of renewed bark above the cut.

Repeated applications of the treatments at six-monthly intervals over a period of three years have not resulted in an increased incidence of 'dry' trees but the yield response is found to decrease with each successive treatment.

Monthly treatment with yield stimulants of renewing bark just above the tapping cut has also resulted in greatly increased yields and in an increase in bark thickness; the latter is confined to the non latex bearing tissues of the outer bark.

The work of the Botanical Division of the Rubber Research Institute of Malaya during the immediate postwar period was concerned largely with the rehabilitation of the field experiments on the Rubber Research Institute Experiment Station and on estates and it was not until early in 1951 that, with the increases in staff, the work on yield stimulation was resumed.

The results obtained in prewar experiments with the use of vegetable oils applied to scraped bark below the cut (BAPTIST 1955) had been ascribed to the presence of natural hormones contained in these oils. It was therefore planned to test the effect on yield of a number of synthetic growth substances, which were available commercially, applied to the bark in an inert carrier.

EXPERIMENTAL

The growth substances used in the first experiment of the new series were:

a 3 - indolyl butyric acid
b 1 - naphthalene acetic acid
c p - chlorophenoxy acetic acid
d 1 - naphthoxy acetic acid
e 2 - naphthoxy acetic acid
f α (2 - naphthoxy) propionic acid

The concentration used was 0.1 per cent in liquid paraffin and, as the chemicals do not dissolve in the oil they were applied as a water in oil emulsion. The emulsions were applied to a three-inch wide strip of bark immediately below a normal half spiral tapping cut on 22 years old seedling trees on both lightly scraped and unscraped bark. A further treatment consisted of light scraping only with no application of growth substances.

The large number of treatments and the limited material available for this experiment necessitated a single 'tree plot' design in which each tree constitutes a treatment plot and the individual tree yields are recorded. The trees were subjected to a period of yield recording before the treatments were applied and the pre-treatment yields were used as a basis for covariance analysis and adjustment of the post-treatment yields.

The results over a period of six months showed that the growth substances *a*, *b*, *c* and *d* at concentrations of 0.1 per cent have a small positive effect on yield, especially *d* (1-naphthoxy acetic acid) which caused an increase of 20 per cent and that treatment *e* (2-naphthoxy acetic acid) has no effect at all. When the mixtures were used at a 1.0 per cent concentration treatment *b* (1-naphthalene acetic acid), treatment *c* (p-chlorophenoxy acetic acid) and treatment *d* (1-naphthoxy acetic acid) gave increases of 27%, 53% and 25% respectively in the first month following the application of the treatment.

In February 1951 Dr G.W. Chapman, Director of the Chemara Central Research Station, Malaya, read at a conference held at the Rubber Research Institute of Malaya an important paper (CHAPMAN 1951) in which he showed the outstanding yield stimulating effect on rubber trees of 2,4-dichlorophenoxy acetic acid (2,4-D) applied in palm oil to scraped bark below the tapping cut. The proprietary yield stimulant 'Stimulex' was developed as a result of this work.

Further experiments carried out at the Rubber Research Institute of Malaya made use of 2,4-dichlorophenoxy acid, at first as the sodium salt of 80 per cent acid equivalent which, as it is insoluble in oil, was used in the form of a water in palm oil emulsion, and later as the normal butyl ester of 80 per cent acid equivalent which is oil soluble. The effects of three concentrations of 2,4-D namely 0.1, 1 and 2 per cent, and of two proprietary yield stimulants have been compared and the results are summarised in TABLE I and graphically presented in *Figure 1*.

The following treatments were applied to a three inch strip of lightly scraped virgin bark immediately below the tapping cut of 22 years old unselected seedling trees which had been tapped for only one and a half years, on the half spiral alternate daily system:

A - 0.1% 2,4-D (Na-salt) in water/liquid paraffin emulsion, increased to 2% from second application onwards.

B - 0.1% 2,4-D (Na-salt) in water/palm oil emulsion, increased to 2% at second application, changed to

2% n-butyl ester of 2,4-D in palm oil from third application onwards.

C - 1% 2,4-D (Na-salt) in water/palm oil emulsion changed to 1% n-butyl ester of 2,4-D in palm oil from third application onwards.

D - 'Stimulex'.

E - 'Eureka'.

F - Scraping a three inch band below the tapping cut only.

O - Control—no treatment.

The principal results of this experiment are discussed below.

The sodium salt of 2,4-D at a concentration of 0.1 per cent either in palm oil or in liquid paraffin has a small, but not statis tically significant, effect on yield. A one per cent concentration of the salt gave a significant yield increase and a further increase of concentration to two per cent resulted in higher peak yields but not in a significantly higher mean yield over a period of six months after application. In both treatments *A* and *B* the yield level in the third and fourth six-monthly periods following treatment with two per cent 2,4-D fell to below that of the control after the initial increase in the first two months. The highest response to the yield stimulant was obtained in the first month after treatment after which the yield decreased in the second and third months to about the level of that of the control trees, followed by a slight increase.

The response to the proprietary stimulants 'Stimulex' and 'Eureka' is not significantly better than that to 2,4-D used either as a two per cent or as a one per cent concentration in palm oil.

The bark scraping treatment alone (in this case virgin bark lightly scraped for three inches below the cut) has had a small but not statistically significant effect on yield.

Some bark damage was caused by the downward flow and accumulation of the mixtures containing 2,4-D on to the virgin bark below the treated strip. The bark affection took the form of swelling, followed by splitting and, in extreme cases as observed on estates, by actual drying up of the bark. This type of bark damage is now largely avoided by thickening the consistency of the palm oil by addition of an inert petrolatum grease such as the Standard Vacuum Product 2295C.

A day to day picture of the peak yield period after the second application of the treatments depicted in *Figure 1* shows the rapidity of the response of *Hevea* trees to yield stimulants applied to a three inch strip of lightly scraped bark below the tapping cut, the maximum increase occurring on the fifth day following the application of the bark treatments (*Figure 2*).

This yield trend has been confirmed in all subsequent experiments.

An experiment to test the effect of successive applications of yield stimulant applied at six-monthly intervals was set up in

TABLE I: YIELDS ADJUSTED ON PRETREATMENT YIELDS AND EXPRESSED AS A PERCENTAGE OF THE CONTROL

Treatments	*A*	*B*	*C*	*D*	*E*	*F*
Mean pretreatment yield in gm/tree/tapping	40.8	43.5	41.3	41.6	39.3	39.5
1st application						
1st month after	114	121	132	140	142	112
2nd month after	105	107	113	114	122	106
3rd month after	109	109	117	117	128	109
Mean 3 months	110	112	120	123	130	109
2nd application						
1st month after	141	176	153	200	167	119
2nd month after	153	161	146	145	158	120
3rd month after	122	115	116	119	123	109
4th month after	112	110	108	119	125	106
5th month after	114	112	119	117	116	110
6th month after	110	112	114	111	109	110
Mean 6 months	128	131	126	132	135	112

Changeover of tapping panels

Mean pretreatment yield in gm/tree/tapping	34.3	32.7	29.5	29.6	32.9	31.8
3rd application						
1st month after	148	171	157	153	147	122
2nd month after	121	121	125	133	120	115
3rd month after	102	98	109	107	109	108
4th month after	94	94	104	108	113	108
5th month after	97	113	124	119	119	101
6th month after	92	110	120	117	107	93
Mean 6 months	108	117	122	122	119	108
4th application						
1st month after	123	161	145	170	150	109
2nd month after	96	119	120	125	112	101
3rd month after	83	94	105	99	94	95
4th month after	84	88	104	108	87	96
5th month after	80	96	115	116	94	99
Mean 5 months	92	111	117	123	106	100

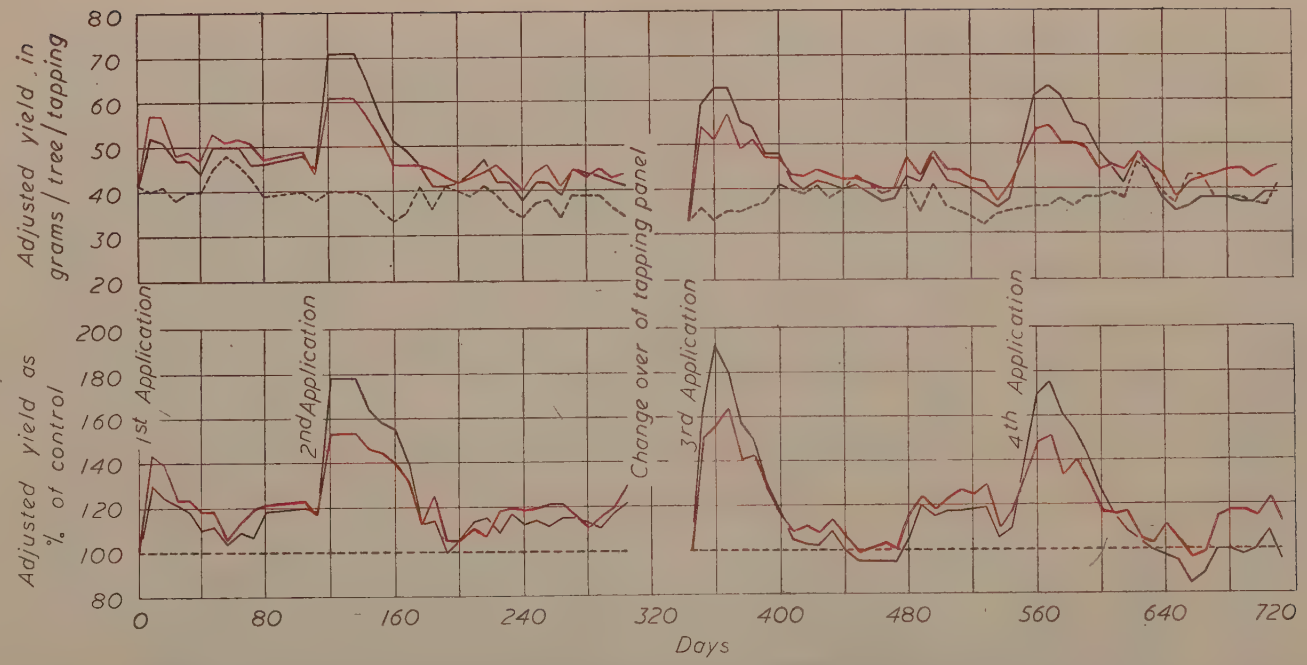

Figure 1. Comparison of the effects on yield of 2,4-D in different concentrations.

0.1% 2, 4-D in palm oil changed to 2% concentration from 2 application onwards

1% 2, 4-D in palm oil ..... *Control*

N.B. The Na salt of 2,4-D of 80% acid equivalent was used at 1st and 2nd application. The n-butyl ester of 2,4-D of 80% acid equivalent was used at 3rd and 4th application.

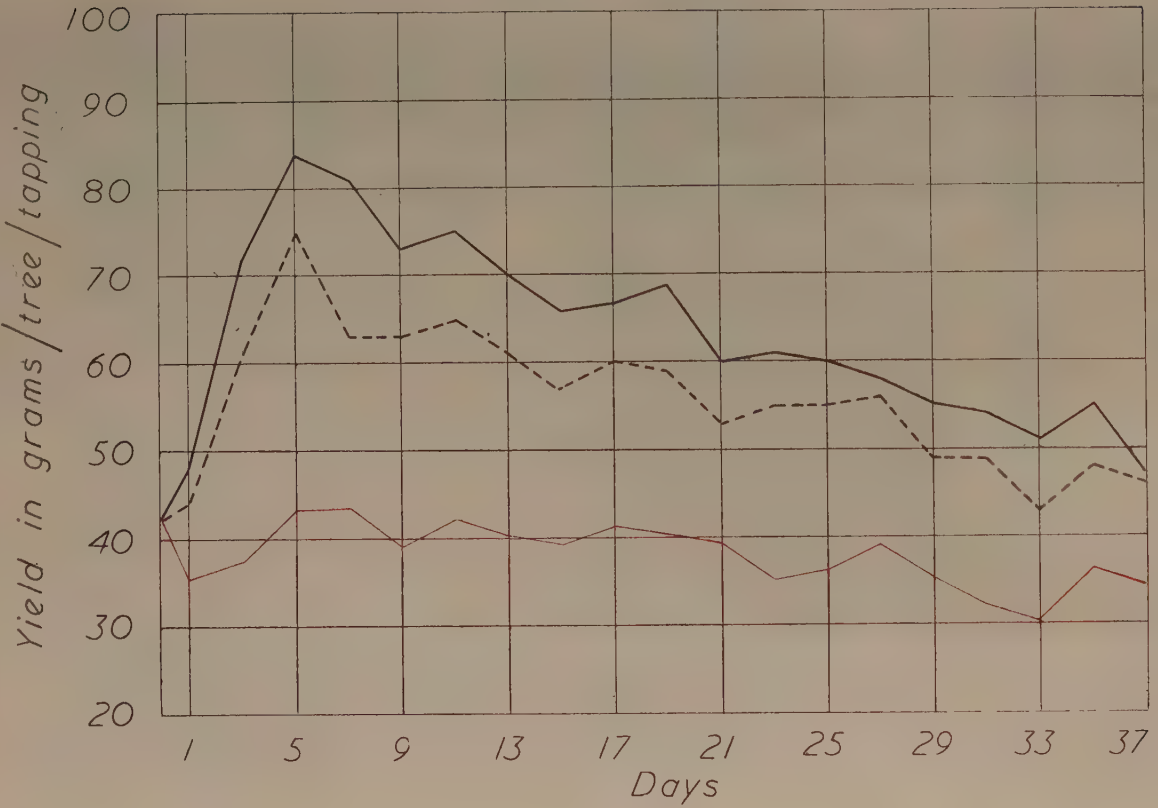

Figure 2. Rapidity of response to yield stimulant. Yields are expressed in grams per tree per tapping.

——— 2% 2,4-D (Na salt) in palm oil

..... 1% 2,4-D (Na salt) in palm oil

——— Control

January 1952 in a field of 20 years old clonal seedling trees (Field 14E Rubber Research Institute Experiment Station) tapped on the half spiral alternate daily system. The area was arranged in 30 blocks each containing 12 trees and the following twelve treatments were allocated randomly within each block. Observed treatment yields have been adjusted by covariance analysis on pre-treatment yields.

A - 'Stimulex'

B - 'Eureka'

C - Palm oil only

D - 1% 2.4-D in palm oil

E - 1% 2.4-D in palm oil plus 1% sulphur (changed to mixture of 2,4-D and2,4,5-T as from third application

F - 1% 2,4,5-T in palm oil

G - Copper sulphate injection

H - Light scraping only (changed to 2,4-D as from second application)

O - Control—no treatment

All treatments were applied to a three inch strip of lightly scraped bark below the tapping cut. The sodium salts of 2,4-D and 2,4,5-T of 80 per cent acid equivalent were used for the first and second applications in the form of water in oil emulsions after which they were replaced by the oil soluble normal butyl esters of the same acid equivalent. The palm oil used as a carrier for the synthetic growth substances was for the third and subsequent applications mixed with an equal quantity of a petrolatum (Standard Vacuum Product 2295C).

The following changes were made to treatments *E* and *H* during the course of the experiment.

	Treatment E	Treatment H
1st application	1% 2,4-D and 1% sulphur	Scraping only
2nd application	1% 2,4-D and 2% sulphur	1% 2,4-D (n-butyl ester)
3rd application	1% 2,4-D and 1% 2,4,5-T	2% 2,4-D (n-butyl ester)

2,4,5-trichlorophenoxy acetic acid (2,4,5-T) in the form of its sodium salt and normal butyl ester of 80 per cent acid equivalent (treatment *F*) was selected because of its relationship to p-chlorophenoxy acetic acid and 2,4-dichlorophenoxy acetic acid which gave good results in previous experiments. The addition of sulphur to the 2,4-D preparation in palm oil (treatment *E*) was to test the claim made by Chapman (1951) that 'elementary sulphur was highly beneficial under certain conditions, when clearly (as judged by the smell) some sulphur compound was formed'. In treatment *G* copper sulphate, shown by COMPAGNON and TIXIER (1950) to be highly effective as a yield stimulant, was injected into trees in two small auger holes two and a half to three inches deep and half inch in diameter bored

TABLE II: COMPARISON OF THE EFFECT OF EIGHT YIELD STIMULATION TREATMENTS

Treatment	*Adjusted mean treatment yields over six months period following each application in grams per tree per tapping and as a percentage of the control*				
	1st period on 1st panel	*After change over to opposite tapping panel*			
		2nd period	*3rd period*	*4th period*	*5th period*
A	62.2 (137%)	45.9 (146%)	39.6 (135%)	41.5 (117%)	43.3 (122%)
B	57.7 (121)	43.1 (136)	39.5 (134)	40.3 (114)	42.2 (119)
C	54.4 (114)	39.0 (124)	34.7 (118)	33.4 (94)	36.7 (104)
D	58.6 (123)	35.9 (114)	31.5 (107)	28.3 (80)	31.0 (88)
E	59.3 (124)	44.2 (140)	45.3 (154)	39.9 (113)	42.0 (119)
F	51.5 (108)	48.5 (154)	45.2 (154)	41.6 (118)	42.5 (120)
G	55.4 (116)	45.7 (145)	38.2 (130)	42.6 (120)	40.1 (113)
H	51.2 (107)	48.1 (152)	45.7 (156)	45.4 (128)	41.6 (118)
O	47.7 (100)	31.6 (100)	29.4 (100)	35.4 (100)	35.4 (100)
Standard error of a mean	± 2.54	± 3.98	± 4.30	± 4.55	± 4.49
Min. 5% sig. difference	7.0	11.1	12.0	12.6	12.4
Min. 1% sig. difference	9.3	14.5	15.7	16.6	16.4

at a downward slope one at each end of the half spiral tapping cut, five grams of the finely powdered salt was introduced into each hole.

The results of this experiment over five periods of six months each are summarised in TABLE II and the yield trends in five selected treatments are shown in *Figure 4*.

It should be noted that for the first and second applications the sodium salts of 2,4-D and 2,4,5-T were applied in the form of a water in palm oil emulsion containing 20 parts of water and 80 parts of oil. The practical difficulty of preparing emulsions of exactly similar physical properties may account for the irregularity obtained in a few cases.

The results over each successive period of six months following the applications of the treatments are discussed in the following pages.

FIRST PERIOD

The first application of the various treatments was made to a three inch strip of lightly scraped bark below a half spiral cut which was then about eight inches from the ground.

The results show a marked increase in yield ($P<0.01$) due to the proprietary stimulants Stimulex (*A*) and Eureka (*B*) and to 1 per cent 2,4-D used as the sodium salt in a water in palm oil emulsion, both with and without the addition of sulphur (*D* and *E*).

The sodium salt of 2,4,5-T as a water in oil emulsion (*F*) did not cause a significant yield increase which, judged by later outstanding response to this material, may have been due to inadequate dispersion of the active chemical in the oil phase of the emulsion.

Light scraping of a three inch wide strip of bark (*H*) had a small effect but addition of palm oil to the scraped bark (*C*) caused a yield increase which is nearly significant at the 5 per cent level ($P<0.05$).

The effect on yield of copper sulphate injection (*G*) was significant at the 5 per cent level.

SECOND PERIOD

The second and subsequent applications of the treatments were made on a new tapping panel opened on the opposite side of the trees at 45 inches from the ground.

The proprietary yield stimulants Stimulex (*A*) and Eureka (*B*) and 1 per cent 2,4-D (sodium salt) with 2 per cent sulphur in a water in palm oil emulsion (*E*) caused yield increases which are significant at the 5 per cent level.

The sodium salt of 2,4-D in palm oil alone (*D*) gave disappointing results which could indicate a beneficial effect of the sulphur which had been thoroughly dispersed into the emulsion of treatment (*E*). The sodium salt of 2,4,5-T (*F*) gave a large yield increase which reached the 1 per cent level of significance.

Palm oil applied to the lightly scraped bark caused a yield increase of 24 per cent which failed to reach the 5 per cent level of significance.

The normal butyl ester of 2,4-D dissolved in palm oil (*H*), used for the first time in our experiments gave a 52 per cent increase in yield which was significant at the 1 per cent level.

Copper sulphate injection gave a yield increase of 45 per cent and was again effective at the 5 per cent level of significance.

THIRD PERIOD

In the third application of treatments the sodium salts of 2,4-D and 2,4,5-T were replaced by the normal butyl esters which had meantime become available commercially. It was now possible to dissolve these salts directly into the palm oil and to improve the consistency of the preparation by addition of the inert petrolatum Standard Vacuum Product 2295C. The mixture used in this experiment consisted of equal parts of palm oil and 2295C but it was found later that one of 5 parts of palm oil and 3 parts of 2295C containing 1 per cent acid equivalent butyl ester of 2,4,5-T could be applied more thinly and evenly to the scraped bark and could be stored for long periods (over two years) free from mould and bacterial growth and with no adverse effect on its yield stimulation properties. The 1 per cent normal butyl ester of 2,4,5-T in palm oil and petrolatum (*F*) used for the first time as a yield stimulant, gave a very high peak yield and an increase in yield of 54 per cent over the period of six months following treatment, significant to the 1 per cent level.

Treatment *E*, now altered to a mixture of 1 per cent normal butyl esters of 2,4-D and 2,4,5-T in palm oil and 2295C, and treatment *H*, now increased to 2 per cent normal butyl ester of 2,4-D in palm oil and 2295C gave increases over the period of six months of 54 per cent and 56 per cent respectively which reached the 1 per cent level of significance. It is noted that these high concentrations are not more effective than the 1 per cent n-butyl ester of 2,4,5-T.

'Stimulex' (*A*), 'Eureka' (*B*), 1 per cent 2,4-D mixture (*D*) and copper sulphate injection (*G*) gave high initial increases but the response over the full period of six months failed to reach the 5 per cent level of significance. The fact that these yield increases are not statistically significant is due mainly to the limited number of trees included in each treatment and does not necessarily imply that the treatments have become ineffective, since during the period under review treatments *A*, *B* and *G* increased the yield by at least 30 per cent over the period of six months. In none of the trees in these three treatments did the yield drop below the pre-treatment level.

A study of the graphical representation of the results in *Figure 4* leaves no doubt of the positive effect of 2,4,5-T and Stimulex after the third application of treatments but the effect of the 1 per cent 2,4-D mixture becomes doubtful since in the last three months of that period the yield level dropped well below that of the pre-treatment yields resulting in an overall yield increase of only 7 per cent over the control (TABLE II).

Palm oil applied to scraped bark (*C*) gave an increase of 18 per cent over the full period of six months.

FOURTH PERIOD

None of the treatments induced a yield increase which was statistically significant and, although there is little doubt of a positive effect of treatments *A*, *B*, *E*, *F*, *G* and *H*, the magnitude of the responses has in general gradually decreased with each successive application. Treatment *D* (1% 2,4-D in palm oil) gave a 54 per cent increase in the first month following treatment but its yield level after the second month dropped well below that of the control and even below that of treatment *C* (light scraping and palm oil), showing an overall decrease of 20 per cent over the six month period.

FIFTH PERIOD

The response to all treatments during this six months period was very much the same as that during the preceding period with the exception of treatment *G* (copper sulphate injection) which gave a smaller increase (45 per cent) in the first month and no increase over the mean yield of the control for the full period of six months following treatment.

SIXTH PERIOD

The results for the first two months of the six monthly period now available show yield increases of the order of 50 per cent during the first month for treatments *A*, *B*, *E*, *F* and *H*. Treatments *C*, *D* and *G* show during the same period yield increases of the order of only 10 per cent.

DISCUSSION

The results for the second and third periods which show the superiority of treatment *F* (1% n-butyl ester of 2,4,5-T) over the other treatments have already been published by R.R.I. MALAYA (1953).

The high value of the standard error caused by the relatively low number of trees allotted to each treatment (30 trees) does not allow for proof of significance, even at the 5 per cent level, from the fourth period onwards when the response to treatments had shown a decline, although there is little doubt of the real effect of a number of treatments. The mean monthly yield data covering a period of two and a half years of this experiment, adjusted by regression on pretreatment yields, (*Figure 4*) show in general a decreasing level of response to treatment with successive half yearly applications.

The superiority of treatment *A* (Stimulex) and treatment *F* (1% n-butyl ester 2,4,5-T) over treatment *D* (1% n-butyl ester 2,4-D) and treatment *G* (copper sulphate injection) is well brought out in this long term experiment, the latter treatments showing after the initial yield increase an appreciable decrease below the yield level of the control. This fall in yield which is shown for the first time during the second treatment period in treatment *D* and during the fourth period in treatment *G* should be taken as a warning for caution in the use of yield stimulants at six monthly intervals in normal commercial tapping. The disappointing performance of 1 per cent 2,4-D (treatment *D*)

Figure 3. Damage to bark caused by injection of copper sulphate.

has not been repeated in other experiments, although a fall in yield level below that of the control occurred after treatment with 2 per cent 2,4-D in a previous experiment (TABLE 1).

It is interesting to note that the three synthetic growth substances which in these experiments have induced the greatest yield response, namely p-chlorophenoxy acetic acid, 2,4-dichlorophenoxy acetic acid and 2,4,5-trichlorophenoxy acetic acid, have in common a chlorine substituted phenoxy group and a carboxyl group, the indications being that the efficacy as a yield stimulant increases with the number of chlorine ions substituted in the phenoxy group.

The use of copper sulphate as a yield stimulant whether by injection (Compagnon and Tixier 1950) or by application in paste form to bark below the tapping cut (WIERSUM 1954) cannot be recommended (BOTANICAL DIVISION 1953) because of the danger of accidental contamination of the latex resulting in an increased copper content of the crop beyond the limits specified for R.M.A. grade of rubber (8 parts per million) by the Rubber Manufacturers Association of New York and for latex concentrates (10 parts per million) by the American Society for Testing Materials. Furthermore, serious bark damage to tapping panels of a fairly high proportion of trees has in our experiments been caused by injection of copper sulphate in auger holes bored into the main stem. An example of severe damage is shown in *Figure 3*.

When comparing the performance of Stimulex with that of n-butyl ester of 2,4,5-T it should be borne in mind that the one per cent concentration of 2,4,5-T used in our long term ex-

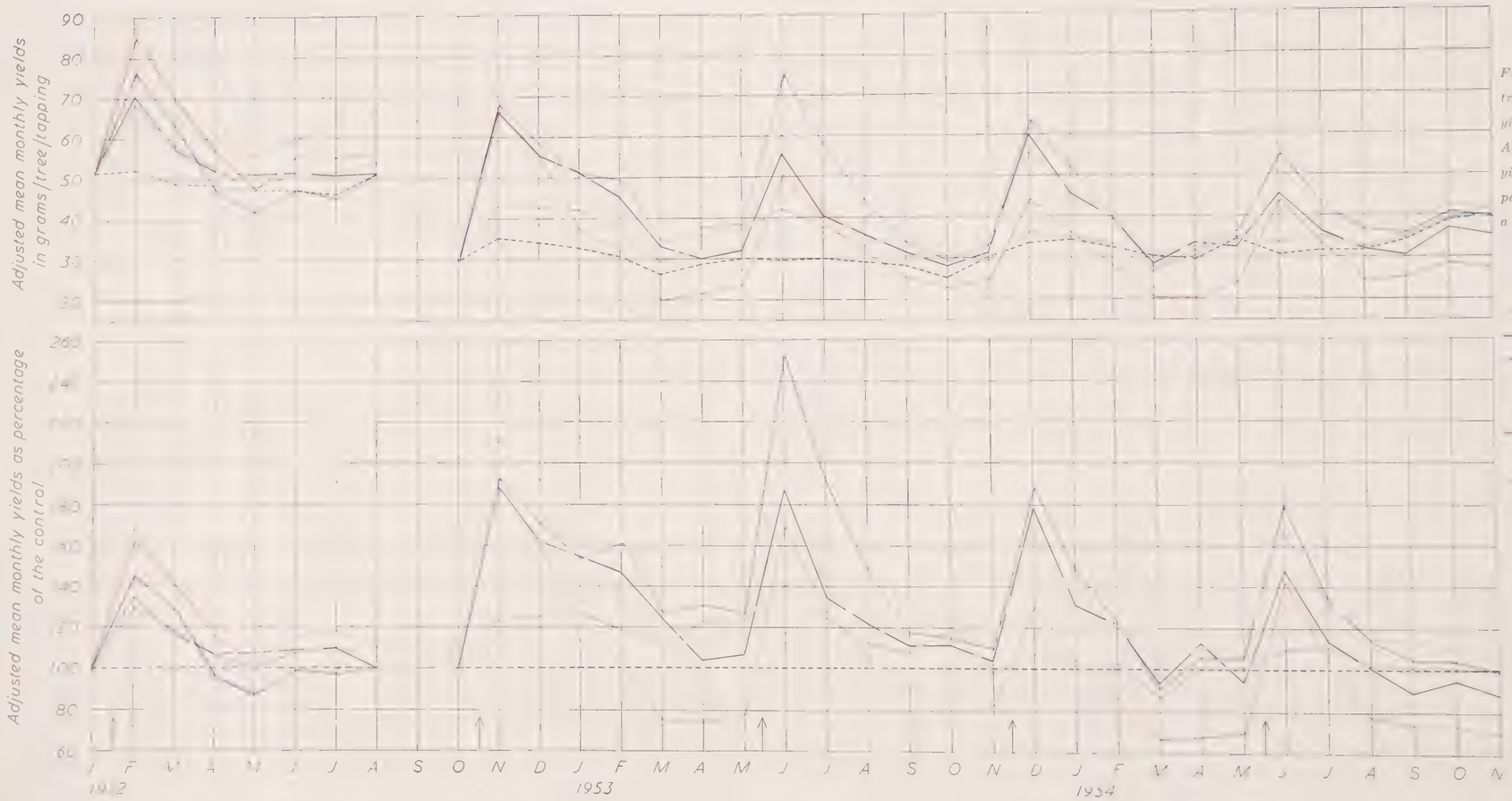

Figure 4. Comparison of five treatments in a long term yield stimulation experiment. Adjusted mean monthly yields are expressed in grams per tree per tapping and as a percentage of the

periment corresponds to one of 0.8 per cent acid equivalent and is therefore weaker than that recommended by the Institute for purposes of yield stimulation. The prescription for a yield stimulant which has been developed as a result of this work and which is manufactured locally by commercial fertiliser firms is the following:

> One and a half fluid ounces of n-butyl ester 2,4,5-T (10 lb per gallon acid equivalent) in a mixture of 5 pints of commercial red palm oil and 3 pints of petrolatum (Standard Vacuum Product 2295C or Shell Otina C).

Full details of the method of preparation of this yield stimulant for use on estates have been issued in leaflet form and patent protection for the use of 2,4,5-T as a yield stimulant has been applied for on behalf of the Industry.

In view of a possible cumulative harmful effect of yield stimulants on the tree we would advise caution in their use on young trees. Provisionally we consider that old trees may be treated once a year, or once in six months if they are due to be cut out within a period of four to five years.

An interesting observation made in the course of this work is that trees treated at six-monthly intervals with a yield stimulating mixture on lightly scraped bark below the tapping cut show a significantly better renewal of bark above the cut. This effect on bark renewal is examined in detail by DE JONGE (1955).

APPLICATION OF YIELD STIMULANTS ABOVE THE TAPPING CUT

Experiments carried out by this Institute before the war had shown that palm oil applied to renewing bark above the tapping cut increased the rate of bark renewal (BEELEY and BAPTIST 1939) but no detectable effect on the yield of latex was demonstrated in those early experiments (BAPTIST 1955). Further experimentation to amplify those findings has been in progress since 1952 on buddings of clone AVROS 50 established in November 1930. The treatments have been applied at monthly intervals to the freshly excised bark of the previous month. Yield recording is done once a week and measurements of bark thickness are made annually. The results are presented separately for each of the first two years of the experiment, the bark thickness measurements in TABLE III and the yield data in TABLE IV.

During the first year the increase in bark thickness with treatments, *3*, *6* and *7* is significantly greater ($P<0.001$) than that of the control but, as shown by anatomical examination of bark sections, it is confined to the outer non latex bearing portion of the bark and has not measurably affected the number of rows of latex vessels. The effects of treatments *2* and *5* are significant at the 5 per cent level but that of treatment *1* (palm oil), although better than that of the control trees, is not established with confidence. In the following year no treatment effects are significant, although again the best responses are shown by treatments *3*, *6* and *7*.

TABLE III: INCREASE IN BARK THICKNESS

Treatment	*Increase in bark thickness in millimetres*	
	First year	*Second year*
1. Palm oil	1.6	0.2
2. Palm oil + 0.1% 2,4-D	1.7	0.3
3. Palm oil + 1.0% 2,4-D	2.9	0.4
4. VP 2295C	1.4	0.2
5. VP 2295C + 0.1% 2,4-D	1.7	0.4
6. VP 2295C + 1.0% 2,4-D	3.7	0.4
7. Stimulex	3.3	0.4
8. Control	1.2	0.2
Standard error of means	± 0.16	± 0.14
Min. 5% sig. difference	0.5	0.4
Min. 1% sig. difference	0.6	0.5
Min. 0.1% sig. difference	0.8	—

The yields of the experimental plots before the application of the treatments were not identical and observed post-treatment yields have therefore been adjusted to correct for these pre-treatment differences. These adjusted yields are presented in TABLE IV.

Treatments *3*, *6* and *7* which gave marked increases of bark thickness in the first year have also resulted in large increases in yield which are significant at the 0.1 per cent level. The yield increases caused by treatments *2* and *5*, containing 0.1 per cent of 2,4-D, are highly significant in the first year while that due to palm oil (treatment *1*) just reaches the 5 per cent level of significance. These observations are believed to be the first to be recorded in which increased yields have been obtained by application of growth promoting substances above the tapping cut. They do not support Chapman's (1951) contention that such a procedure depresses yield.

The responses to treatments are smaller in the second year. The yield increases shown by treatments *3*, *6* and *7* remain significant at the 0.1 per cent level but those due to palm oil (treatment *1*) and palm oil with 0.1 per cent 2,4-D (treatment *2*) are not proven.

TABLE IV: TREATMENT YIELDS

Treatments	First year		Second year	
	Adjusted post-treatment mean yields (gm/tree/tapping)	Adjusted post-treatment yields as % of control	Adjusted post-treatment mean yields (gm/tree/tapping)	Adjusted post-treatment yields as % of control
1. *Palm oil*	16.9	113	18.5	107
2. *Palm oil + 0.1% 2,4-D*	18.2	122	16.4	95
3. *Palm oil + 1.0% 2,4-D*	25.6	172	25.7	148
4. *VP 2295C*	16.3	109	16.1	93
5. *VP 2295C + 0.1% 2,4-D*	17.3	116	19.2	111
6. *VP 2295C + 1.0% 2,4-D*	21.7	145	21.5	124
7. *Stimulex*	24.4	163	22.8	132
8. *Control*	14.9	100	17.3	100
Standard error of adjusted post-treatment mean yields	± 0.64		± 0.64	
Min. 5% sig. difference	1.8		1.8	
Min. 1% sig. difference	2.4		2.4	
Min. 0.1% sig. difference	3.2		3.2	

The yield trend of three selected treatments applied each month above the tapping cut to bark excised during the previous month is shown in *Figure 5*. The best results over the two years have been obtained with 1 per cent 2,4-D in palm oil and with Stimulex in the order given while 0.1 per cent 2,4-D fails to maintain its lead over the control in the second year. A feature of the graph is that the yield curves do not exhibit the marked initial peak responses shown in *Figure 4* where application of the yield stimulants were made at intervals of six months to bark below the tapping cut. The relative yield curves (*Figure 5b*) show two peaks which coincide with the drop in yield of the control trees (*Figure 5a*) during the dry month of February in each of the two years.

The method of application of a yield stimulant above the tapping cut is undergoing comparison with several other methods in an experiment on a mixed stand of mature budded trees of clones AVROS 50 and Pilmoor D 65, budded in October 1931, and tapped on weak renewed bark. The yield stimulant used is the normal butyl ester of 2,4,5-T at a concentration of 1 per cent acid equivalent in a mixture of palm oil and petrolatum.

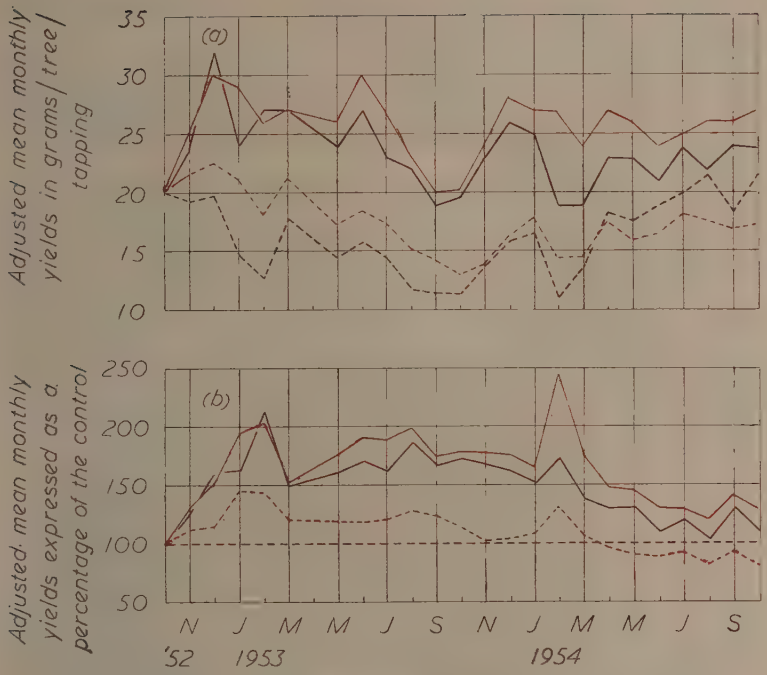

Figure 5. Yield trend after application of stimulant above the tapping cut. Adjusted mean monthly yields are expressed in grams per tree per tapping and as a percentage of the control.

——— *Stimulex*

——— *1% 2, 4 - D in palm oil*

. . . . . *0.1% 2, 4 - D in palm oil*

. . . . . *Control*

The following treatments have been included:

A Yield stimulant applied at intervals of six months to a three inch strip of lightly scraped bark below the tapping cut.

B Yield stimulant applied at intervals of six months to a three inch strip of unscraped bark below the tapping cut.

C Yield stimulant applied at intervals of six months to a three inch strip of lightly scraped bark on a half circumference of the stem at a height of 5 feet above the tapping panel.

D Yield stimulant applied above the tapping cut at intervals of one month to the width of bark excised during the previous month.

O Control—no treatment.

The available yield data for the first three months of this experiment are summarised in TABLE V.

Examination of the table shows the clear effect on yield of light scraping of the bark (by comparison of treatments *A* and *B*), the small effect of treatment *C* and the most promising effect of treatment *D* which confirms that established in the previous experiment (TABLE IV).

The design of this experiment allows for a comparison of the response to yield stimulants by high yielding and low yielding plots. The yield trends of the highest yielding and of the lowest yielding plots of treatments *A* and *D* are shown in *Figure 6*.

The graphs clearly demonstrate that the higher yielding trees respond much better than the lower yielding trees to yield stimulant applied to a three inch strip of lightly scraped bark below the cut (treatment *A*) and that for lower yielding trees the method of monthly application of yield stimulant to freshly tapped bark of the previous month (treatment *D*) is greatly superior to the more conventional treatment *A*.

The mean yield data show that initially, over the first seven weeks of the experiment, treatment *A* is more effective than treatment *D* but thereafter its effect declines. Over the completed period of three months the mean effect of treatment *D* is slightly superior to that of treatment *A*, as shown by the mean yield increases of 68 per cent and of 56 per cent respectively. For the lower yielding trees the best response by far has been obtained with treatment *D* which caused a total yield increase of 149 per cent compared with an increase of approximately 34 per cent for treatment *A*.

The difference in the shape of the yield curves is presumably due to the frequency of treatment. The yield curve in treatment *A*, in which the yield stimulant is applied below the cut at intervals of six months, shows an initial peak rise followed by a fall while that in treatment *D*, in which applications of the yield stimulant are made above the cut at monthly intervals, shows a more gradual rise to a level which for the present is being sustained.

However we do not recommend for commercial practice the new method of applying the yield stimulant to recently tapped bark above the tapping cut, we need to know whether future results will reveal no adverse effects on yields, incidence of brown bast and on the anatomical structure of the renewed bark.

SUMMARY

The experiments described follow pre-war work on yield stimulation undertaken at the Rubber Research Institute of Malaya.

It is shown that a number of synthetic growth substances applied in an oil vehicle to a narrow strip of bark below the tapping cut, after light scraping, can induce large increases in yield. A secondary effect appears to be some stimulation of the rate of bark renewal.

TABLE V: YIELDS AS GRAMS OF DRY RUBBER PER PLOT (16 TREES) AND AS A PERCENTAGE OF THE CONTROL

Treatments	*A*	*B*	*C*	*D*	*O*
Mean pre-treatment yields	149 (103%)	138 (95%)	147 (101%)	139 (96%)	145 (100%)
Mean yields after treatment					
first month	269 (164%)	222 (135%)	180 (110%)	231 (141%)	164 (100%)
second month	241 (140%)	214 (124%)	187 (109%)	275 (160%)	172 (100%)
third month	194 (111%)	183 (105%)	164 (94%)	273 (157%)	174 (100%)

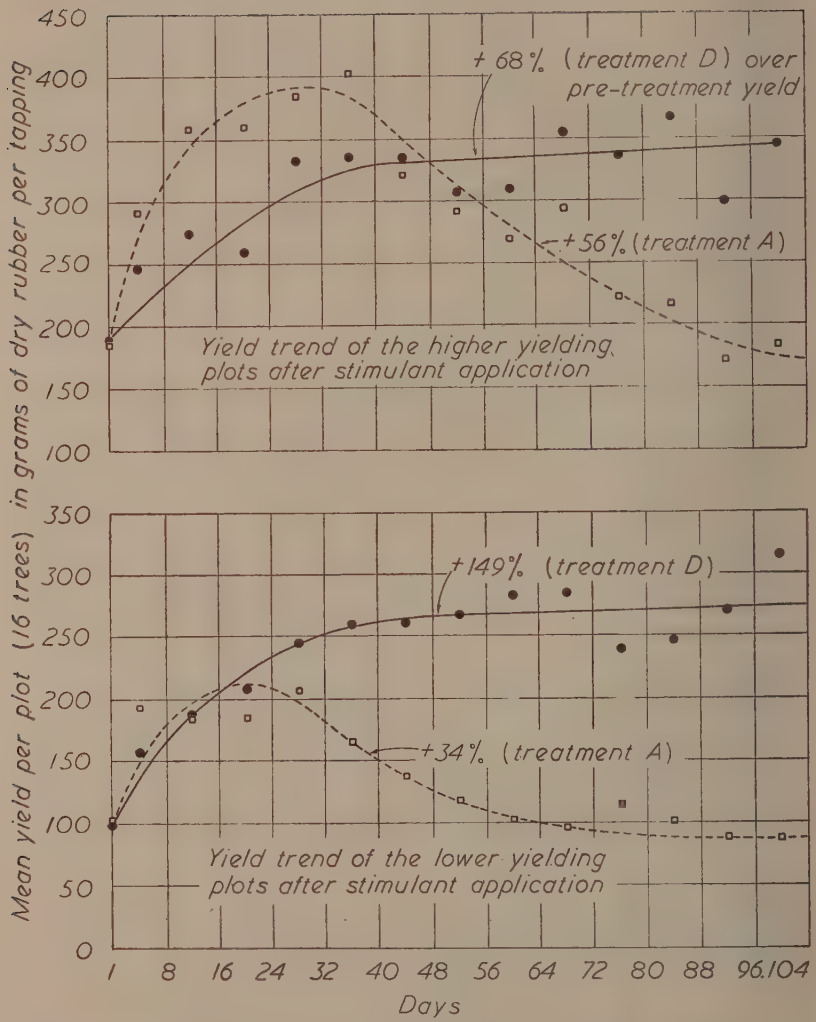

Figure 6. Comparison of two methods of application of yield stimulant. Mean yield per plot (16 trees) expressed in grams of dry rubber per tapping.

Application of yield stimulant on 3 inch strip of scraped bark below the tapping cut once in 6 months.

Application of yield stimulant on 1 inch strip of freshly tapped bark immediately above the tapping cut once monthly.

Each dot represents the mean yield of 4 tapping days.

The most marked responses are recorded in the present experiments with salts and esters of chlorine-substituted phenoxy acetic acids. Comparable responses in yield have been obtained with injections of copper sulphate.

Despite very large, though temporary, increases in yield the incidence of 'dry' trees has not been significantly increased after six consecutive treatments with yield stimulating preparations, applied at intervals of six months to lightly scraped bark below the tapping cut on high yielding seedling trees. Injections of copper sulphate have produced similar effects.

The magnitude of the response has shown a steady decrease with each successive treatment.

Yield stimulant mixtures applied at monthly intervals above the tapping cut, application being restricted to the strip of bark excised during the previous month, have resulted in greatly increased yields. The effect on bark renewal also appears to be quite beneficial, though it has been noted that increase in thickness of the renewed bark, at least in the early stages of renewal, is confined to the non latex bearing tissues of the outer bark.

We express our sincere thanks to Mr C.E.T. Mann, Director of the Institute who, as former Head of the Botanical Division, established the wide range of material on which our experiments have been carried out and for his helpful suggestions and interest in this work.

We are indebted to Mr D.R. Westgarth for his guidance in the design of the experiments and for the statistical analysis of the results.

It is a pleasure to place on record our appreciation of the able assistance of Mr O. Karunakaran and Mr T.S. Aiyar in the field work and of Mr Chen Khuan Tai and Mr Fong Fook Lam in the preparation of the data for publication.

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March 1955

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STIMULATION OF YIELD IN HEVEA BRASILIENSIS
III. FURTHER OBSERVATIONS ON THE EFFECTS OF YIELD STIMULANTS

By

P. DE JONGE

Various factors which influence the response of Hevea trees to yield stimulants are discussed.

A study has been made of the effects of 2,4-D and 2,4,5-T on the rubber extraction area of the bark on tapping, brown bast incidence, rate and duration of latex flow, anatomical structure of the bark and the properties of latex and dry rubber.

It has been shown in the first two papers of this series (BAPTIST 1955), (BAPTIST and DE JONGE 1955) that increases in yield are obtained by application to the bark of rubber trees of vegetable oils and that the effect is greatly enhanced by addition to the vegetable oils of certain synthetic growth substances, notably 2,4-dichlorophenoxyacetic acid and 2,4,5-trichlorophenoxyacetic acid.

It was noted in the course of this work that the magnitude of the yield response to stimulants shows considerable variation between individual trees and, in the case of budded trees, between clones and trees of the same clone grown under different conditions. The main factors causing this variation would seem to be the condition of the treated bark; the age and yield capacity of the tree; soil and climatic conditions; the tapping system; differences in the composition and in methods of application of the yield stimulants.

Further observations have been carried out on the effect of yield stimulants on the bark, with special reference to the incidence of brown bast, changes in bark anatomy, yield trend and changes in the properties of latex and rubber.

FACTORS WHICH INFLUENCE THE RESPONSE TO YIELD STIMULANTS

CONDITION OF BARK

Large increases in yield have been obtained from virgin bark and satisfactorily renewed bark of seedling and budded trees but old seedling trees with thin and corrugated renewed bark, which condition predominates in old seedling plantings, have given disappointing responses because of the severe wounding caused by scraping bark in the poor condition.

In an experiment carried out on buddings of a clone of

TABLE I: MONTHLY YIELD RECORDS EXPRESSED IN GRAMS OF AIR DRIED RUBBER PER TREE PER TAPPING

Clone	*High (ladder) tapping on virgin bark*		*Normal tapping on bark of first renewal*	
	AVROS 50	*BD 10*	*AVROS 50*	*BD 10*
Pre-treatment yields	10.1	63.0	5.4	25.9
Treatment applied				
Yields during first month	42.0	137.0	23.0	48.8
Yields during second month	31.0	107.5	21.5	44.0
Yields during third month	21.7	93.9	17.6	32.3
Yields during fourth month	14.4	80.1	13.0	27.3
Yields during fifth month	10.1	62.2	10.8	19.2
Yields during sixth month	12.4	51.9	9.8	18.6
Mean for 6 months	21.9	88.8	16.0	31.7

Hevea spruceana which yielded only two grams of rubber per tree per tapping and had only three to five rows of latex vessels in the 'bark', or about one tenth of the number found in high yielding trees of *Hevea brasiliensis*, treatment with a yield stimulant resulted in a high relative yield increase but the actual yield increase was only one of 2.5 grams of dry rubber per tree per tapping over a period of three months after treatment. This serves as a good example that on low yielding trees a high relative increase is not necessarily an economic one.

The anatomical structure of the bark may become unsatisfactory under adverse conditions for the normal growth and development of the tree. Such conditions may lead to the formation in the bark of large quantities of stone cells which frequently form continuous layers between the rows of latex vessels and may be expected to interfere with the free translocation of materials within the tissues. This condition of super abundance of stone cells in the bark has been noted in the bark of trees in certain rubber areas in which trees have either ceased to yield or are yielding very little latex.

In one such area situated on a peaty clay coastal alluvium a yield stimulation experiment was set up in a mixed planting of budded trees of clones AVROS 50 and BD 10 which yielded per tree per tapping an average of 5 and 26 grams of rubber respectively. Tapping in half of the area was continued alternate daily on the existing half spiral cut. In the other half new half spiral cuts were opened in virgin bark at a height of 30 inches above the top of the old tapping panel. After one month of preliminary yield recording, a yield stimulant, consisting of a one per cent acid equivalent concentration of 2,4-D in a mixture of palm oil and Vacuum Product 2295C, was applied to a lightly scraped three inch wide strip of bark below the tapping cut. The results covering a period of six months after the application of the bark treatment are presented in TABLE I.

The decline in yield of clone AVROS 50 to an unprofitable level after the third month would make treatment with yield stimulant uneconomic although the percentage increases over the pretreatment yields are considerably higher in this clone than in the higher yielding clone BD 10. Large increases in yield have been obtained by high tapping before the application of yield stimulant, especially in the case of clone BD 10 which did not show the abnormal bark condition observed in clone AVROS 50. For both clones the best returns are obtained by treating high cuts on virgin bark with yield stimulant.

The tapping of high cuts treated with yield stimulant has also given the best results on old seedling trees with thin corrugated bark at normal levels and it is the general experience that the drop in yield normally experienced near the junction of virgin and renewed bark is prevented or at any rate greatly reduced by treatment with yield stimulant.

CLONAL CHARACTERISTICS

The response of nine clones to yield stimulant applied every six months to a three inch strip of second renewal bark below the tapping cut has shown some interesting differences in the first one and a half years. The yield data are summarised in TABLE II.

TABLE II: MEAN YIELDS IN GRAMS OF DRY RUBBER PER TREE PER TAPPING AND AS A PERCENTAGE OF PRE-TREATMENT YIELDS

Field 5 RRI Experiment Station

Clone	*Pre-treatment yields Jan-Apr '53*	*Mean yields over periods of six months after treatment with yield stimulant in gram/tree/tapping and as % of pre-treatment yields.*		
		First period	*Second period*	*Third period*
AVROS 49	26.8	35.2 (131%)	30.9 (115%)	33.2 (124%)
AVROS 50	31.3	41.3 (132%)	43.1 (138%)	31.2 (100%)
AVROS 152	43.9	60.0 (137%)	50.4 (115%)	41.4 (94%)
PB 23	25.6	37.6 (147%)	41.7 (163%)	30.3 (118%)
PB 186	39.4	42.9 (109%)	38.9 (99%)	33.0 (84%)
BD 5	21.5	34.6 (161%)	30.5 (142%)	19.4 (90%)
Tjir 1	50.1	63.1 (126%)	52.3 (104%)	47.6 (95%)
Pil A44	36.3	58.4 (161%)	58.3 (161%)	40.7 (112%)
Pil B84	41.7	47.2 (113%)	46.4 (111%)	42.4 (102%)
Mean of all clones (treated)	35.2	46.7 (133%)	43.6 (124%)	35.4 (101%)
Mean of a'l clones (not treated)	32.6	32.2 (99%)	31.4 (97%)	26.8 (82%)

The decreasing response observed for some clones in the second six-monthly period and a further decrease for nearly all clones shown by the yield records of the third period confirm our previous findings of a decreasing level of response to yield stimulant with successive half yearly applications (BAPTIST and DE JONGE 1955).

Some differences are found in the response of the clones to

yield stimulant, clones Pil A44 and PB 23, reacting the most favourably and clones PB 186 and Pil B84 the least favourably.

TAPPING SYSTEMS

Most of our experiments on yield stimulation have been carried out on trees tapped on the half spiral alternate daily system (S/2.d/2.100%). The influence of tapping systems on the response of trees to yield stimulants was noted by CHAPMAN (1951) who stated that 'trees on daily or slaughter tapping systems do not react well to treatment with hormone preparations and should not be treated with them'. He further claimed that trees tapped on the full spiral fourth daily system (S/1.d/4.100%) gave a good increase in yield but with much late dripping, especially during the peak yield period when latex flow often lasted overnight.

In our investigations yield stimulants applied at intervals of four months to trees in slaughter tapping (BOTANICAL DIVISION 1954) have shown a decreased response with increase of tapping intensity and a substantial saving in tapping costs when combined with a multiple cut system of only moderate intensity.

The first experiment was carried out on clonal seedling trees of 22 years of age yielding approximately 800 lb per acre per year and these were intensively tapped on two half spiral cuts in renewed bark and on one full circumference cut opened in virgin bark, the latter being tapped upwards in such a way that the bark shavings are taken from the upper side of the cut which progresses in an upward direction. The cuts were tapped alternate daily (2C/1.d/2.400%), third daily (2C/1.d/3.267%) and fourth daily (2C/1.d/4.200%). The yield stimulant was applied at four-monthly intervals to half the number of trees allotted to each tapping system, the application being made to a three inch strip of lightly scraped bark below the downward tapped and above the upward tapped cuts.

The trees in alternate daily tapping gave in the first few months of tapping a large increase in yield which dropped steeply as the trees became exhausted after six months of continuous tapping. The use of a yield stimulant on trees tapped on this system resulted in a high initial increase in yield only during the first month, the mean yield over a period of six months being slightly less than that of the trees not treated with yield stimulant. Third daily tapping gave a fair initial increase in yield which over a period of one year was not appreciably increased by treatment with a yield stimulant. Fourth daily tapping proved disappointing on the whole but when combined with the use of yield stimulant resulted in a very large increase in yield, making this system the most attractive of all slaughter tapping systems used in the experiment.

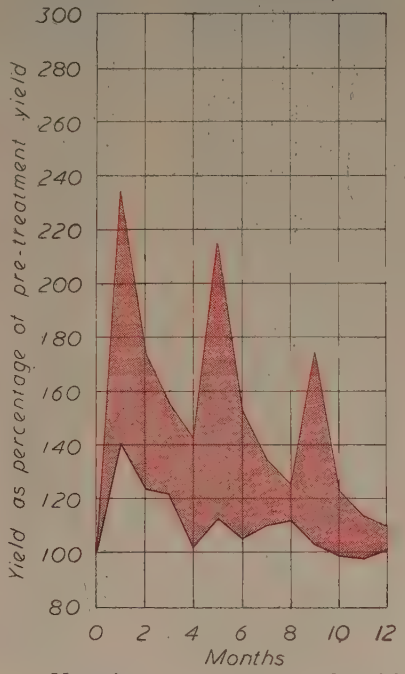
The yield trend in three tapping systems with and without treatment with yield stimulant is shown graphically in *Figure 1* which clearly demonstrates the decreasing response to yield stimulant with increase in tapping intensity.

In a similar experiment carried out on 45 years old unselected seedling trees of large size yielding approximately 400 lb

Figure 1. Slaughter tapping with and without yield stimulant.

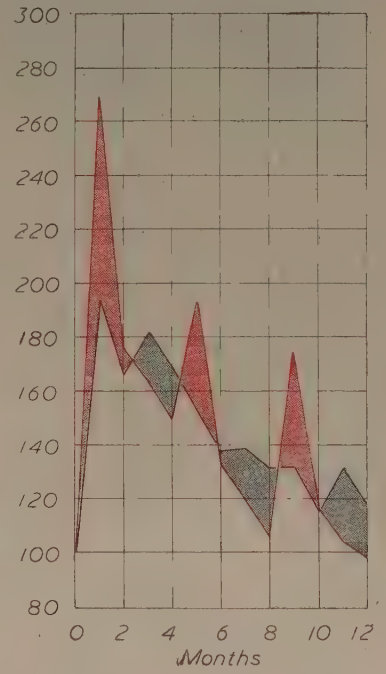
with stimulant — *without stimulant* — *increase due to stimulant* — *decrease due to stimulant*

Tapping system 2 c/1. d/4. 200%



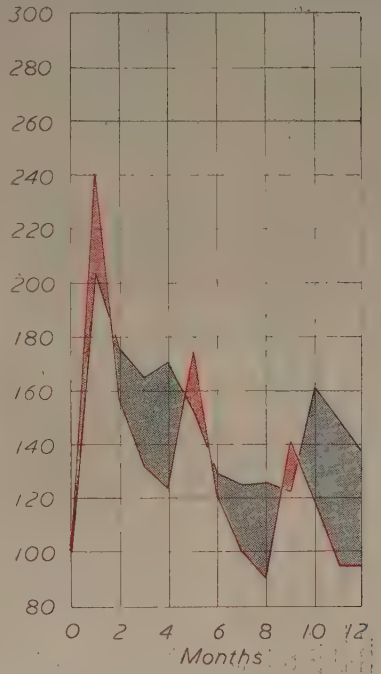
Mean increase over 12 months with stimulant + 55% without stimulant + 11%

Tapping system 2 c/1. d/3. 267%



Mean increase over 12 months with stimulant + 50% without stimulant + 47%

Tapping system 2 c/1. d/3. 627% for 9 mths and 2 c/1. d/2. 400% for 3 mths.



Mean increase over 12 months with stimulant + 32% without stimulant + 51%

per acre per year considerably larger relative yield increases were obtained in all the slaughter tapping systems. Here also none of the high intensity systems yielded significantly more than the moderate intensity system 3V/2.d/4.150% combined with yield stimulant treatment at four-monthly intervals which over a period of one year resulted in a three fold increase of the pre-treatment yield on the half circumference alternate daily system S/2.d/2.100%, with a considerable saving in tapping costs.

In an experiment on the nine clones shown in TABLE II (Field 5 Rubber Research Institute Experiment Station) the response to yield stimulant of two tappings systems, namely the half spiral alternate daily system (S/2.d/2.100%) and the double four system (2S/2.d/4.100%) in which two half spiral cuts, one on each side of the tree, are tapped every fourth day, has been compared over three six-monthly periods following treatment with yield stimulant and the results are presented in TABLE III.

Examination of the data in TABLE III shows that during the pre-treatment recording the yield per tree per tapping is lower for the system with two half spiral cuts tapped fourth daily than for the half spiral alternate daily system. This is due to a retarding effect on growth of continuous full circumference tapping of budded trees from the time they reached tappable size, which in this case resulted in an average loss of girth of five inches over the period 1937 to 1953 for trees tapped on the 2S/2.d/4.100% system compared with the trees tapped on the S/2.d/2.100% system.

In the circumstances a comparison of the response to yield stimulant by the two tapping systems would not be strictly valid. Both systems show over a period of one and a half years nearly the same actual increase in yield when expressed as grams per tree per tapping but when expressed as lb per tree per annum the actual increase for the S/2.d/2.100% system is much higher. This is caused by the double frequency of tapping in this system compared with the 2S/2.d/4.100% system.

The relative yield figures in TABLE III are, moreover, not comparable because of the large differences in the yield of the control trees in these two treatments but the actual and relative yield figures indicate higher peak yields for the 2S/2.d/4.100% system after the first and second application of treatments. This can be accounted for by the large quantity of yield stimulant applied per tree when a three inch band of bark was treated below both half spiral tapping cuts in this 'double four' system.

AMOUNT OF GROWTH SUBSTANCE APPLIED PER TREE

Our experiments have shown that a concentration of one per cent of growth substance (2,4-D or 2,4,5-T) in an oil carrier has generally given the best results when applied to a three inch strip of lightly scraped bark below the tapping cut (Baptist and de Jonge 1955).

TABLE III: YIELDS EXPRESSED IN GRAMS OF AIR DRIED RUBBER PER TREE PER TAPPING AND AS A PERCENTAGE OF THE CONTROL

Tapping system	*S/2.d/2.100*			*2S/2.d/4.100*		
	Treated	*Control*	*Treated as percentage of control*	*Treated*	*Control*	*Treated as percentage of control*
Mean pretreatment yield of all clones (Jan-Apr 1953)	35.2	32.6	108	29.3	30.1	97
First treatment						
Yields during						
first month	60.8	29.8	204	62.9	23.8	264
second month	56.2	34.8	161	51.5	25.8	200
third month	47.7	34.8	137	44.2	28.0	158
fourth month	41.1	32.6	126	32.7	23.6	136
fifth month	38.2	31.0	123	29.6	24.8	119
sixth month	36.8	30.1	121	23.1	17.9	129
Mean of six months	46.7	32.2	145	40.7	24.0	167
Second treatment						
Yields during						
first month	48.5	30.2	161	41.2	22.4	184
second month	52.5	32.8	160	55.4	28.1	197
third month	47.0	33.6	140	43.2	27.6	157
fourth month	43.8	32.6	134	32.2	21.2	152
fifth month	37.4	28.9	129	25.4	19.1	133
sixth month	32.4	30.8	107	21.0	19.3	158
Mean of six months	43.6	31.4	139	36.4	23.0	158
Third treatment						
Yields during						
first month	37.1	34.2	108	26.7	24.8	108
second month	56.8	34.0	167	47.6	22.6	211
third month	29.3	20.9	140	36.1	24.4	148
fourth month	28.6	22.1	129	31.3	24.7	127
fifth month	29.5	23.1	128	22.2	20.5	108
sixth month	31.2	26.4	118	22.3	21.0	106
Mean of six months	35.4	26.8	132	31.0	23.0	135
Mean over period of 18 months	41.9	30.1	139	36.0	23.3	155
Mean actual increase in:						
grams/tree/tapping	+ 11.8			+ 12.7		
lb/tree/annum	+ 4.2			+ 2.3		

A concentration of 0.1 per cent had only a small effect on yield while a concentration of 2 per cent resulted in higher peak yields but showed no advantage over a concentration of 1 per cent over periods of six months following treatment.

The concentration of one per cent acid equivalent of the n-butyl ester of 2,4,5-T currently recommended for yield stimulation would appear to be slightly more effective than that of 0.8 per cent used in our experiments.

One gallon of a yield stimulant containing one per cent acid equivalent of 2,4,5-T in a mixture of five parts of palm oil and three parts of petrolatum has been found to be sufficient for the treatment of approximately 600 trees of a mean girth of 30 inches at the height of application to a three inch strip of bark below a half circumference cut, the calculated quantity applied per tree being 7.5 millilitres of the mixture which is considered by us to be optimal.

If this quantity is greatly exceeded by applying the stimulant either too thickly or to a bark surface exceeding the recommended width of three inches below a half circumference cut, higher peak yields will be obtained but, according to our experience, these initial high yields will drop below the yield level of the non treated trees and extensive bark damage may be caused.

In experiments in which the yield stimulant was applied at monthly intervals above the tapping cut to bark excised during the previous month, the quantity of yield stimulant applied to each tree over a period of six months is nearly double that applied at six-monthly intervals to a three inch wide strip below the tapping cut. The smaller quantity of yield stimulant applied each month above the tapping cut resulted in a yield trend characterised by the absence of peak yields and by a rise in yield level which is sustained for the duration of the experiment (Baptist and de Jonge 1955).

BROWN BAST INCIDENCE

The cause of brown bast, a physiological 'disease' of the laticiferous system, has not yet been established with certainty but observations indicate that it could be due to excessive latex extraction leading to a disturbance of an existing equilibrium between growth and rubber formation.

High yielding trees are in general more prone to brown bast than low yielding trees and a high incidence of the 'disease' may be markedly reduced by a change to a tapping system of lower intensity. This response provides some indication that the amount of latex extracted from the tree has an imortant bearing on the incidence of brown bast and if we accept Frey Wyssling's hypothesis that in normal tapping the area of bark which contributes to the latex yield is situated mainly below the tapping cut and does not exceed a vertical distance of three to five feet depending on the yield capacity of the tree (FREY WYSSLING 1932) it would appear that a too heavy latex withdrawal from this limited area is conducive to brown bast.

Figure 2. Brown bast affected tree treated with yield stimulant. The tapping cut was reopened after the tree had been rested for six months.

Mean yield before treatment with yield stimulant 10.9 grams per tapping. Mean yield for three and half months after first treatment with yield stimulant 85.0 grams per tapping. Mean yield for six months after second treatment with yield stimulant 91.0 grams per tapping. Mean yield for three months after third treatment with yield stimulant 66.0 grams per tapping.

The dry patches on the burred portion of the panel persisted throughout the duration of the experiment.

If, therefore, the use of a yield stimulant results in an increased yield of latex from this bark area an increased incidence of brown bast could be expected. In none of our yield stimulation experiments, however, have the large increases in yields resulted in an increased incidence of brown bast but, on the contrary, trees which had been rested for six months after showing symptoms of brown bast showed increases in yield after treatment with a yield stimulant and these increases have been maintained for a period which has already exceeded two years. The dry patches on the partly diseased panel were not made to yield latex by the yield stimulant which affected only the healthy older latex vessels and those formed during the rest period.

A tree rested for six months because of brown bast and treated with yield stimulant on resumption of tapping is shown in *Figure 2.*

A similar effect was obtained by injection of copper sulphate into the main stem of trees affected by brown bast (TIXIER 1951).

It has been shown, however, in our experiments that when trees showing the first signs of brown bast are kept in tapping and injected with copper sulphate the yields, after a small initial increase, continue to decrease until the trees go dry, thus showing that yield stimulants are no cure for brown bast.

If the cause of brown bast is excessive latex extraction from a limited area of bark, the absence of an increased brown bast incidence in rubber trees treated at regular intervals with yield stimulant would suggest an increase in the area of rubber extraction. This possible effect of yield stimulants has been

investigated using Ferrand's method of determination of the total solids of latex in situ (FERRAND 1941), as modified by GOODING (1951).

For this experiment two budded trees of clone Tjir 1 of similar girth, bark thickness and yield were selected. The trees budded in 1938 had been in regular tapping for only one year on the half spiral alternate daily system (S/2.d/2.100%). Latex samples were taken according to the sampling chart shown in *Figure 3* on each tapping day by piercing the bark with a strong dissecting needle, believed to be an improvement on the narrow scalpel blade used by Gooding in still further reducing any dilution effect of the sampling operation, and were dried and weighed for determination of total solids.

Latex samples were obtained from both trees on each of eight successive tapping days after which one tree was treated with a yield stimulant containing 2,4,5-T at a concentration of 1 per cent acid equivalent.

The sampling of latex was continued on each tapping day and the values given for total solids in TABLE IV represent the mean of eight successive samplings both before and after treatment with yield stimulant. In addition the latex yield of each tapping and the rate and duration of latex flow were measured.

The principal results of this experiment derived from examination of the data in TABLE IV are as follows:

The first period covers eight successive tapping days before the yield stimulant was applied to one of the two trees.

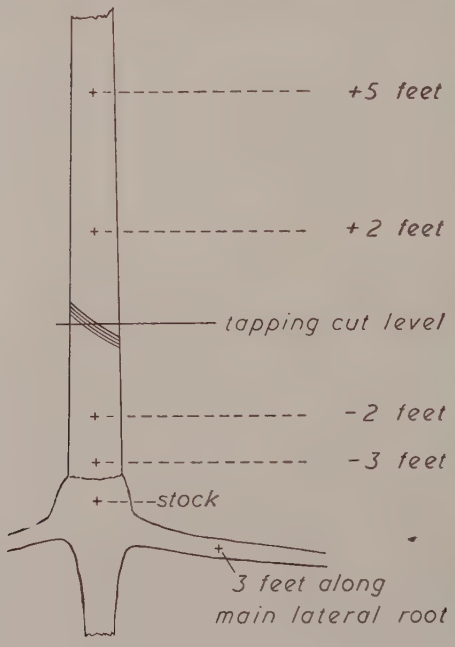


Figure 3. Chart for study of dilution in latex vessels showing sampling points at 2 feet and 5 feet above the tapping cuts and 2 feet and 3 feet below, also in the stock and lateral root.

A slight dilution on one tree at two feet above the tapping cut and no appreciable dilution on both trees at five feet above the tapping cut were observed two hours after tapping. As expected the most pronounced dilution was found at two to three feet below the tapping cut and a clear effect was also noted in the rootstock of both budded trees at a position approximately three and a half feet below the tapping cut but no dilution

effect was detected in the lateral roots.

The tree treated with the yield stimulant at the end of September 1954 reacted with a relatively slow increase in yield which reached its highest value in November.

The second period covers eight successive tapping days in October, before the peak yields were reached and the third period covers eight tapping days at the time of the peak yields in November.

The values for total solids show a clear dilution effect at all sampling points in the tree treated with yield stimulant. Even before tapping all values for total solids are already lower than they were during the pre-treatment period and a further marked dilution occurred at all sampling points after tapping. No appreciable changes are found for the control tree during these three periods, except for a slight increase in total solids at all positions below the tapping cut.

Dilution in the latex vessels after tapping would imply a reduction in turgor pressure and movement of latex towards the cut. These results therefore, would indicate that in the tree treated with yield stimulant a greatly increased area of bark contributes to the latex yield.

During the fourth period which covers eight successive tapping days in January and the beginning of February 1955 a severe drop in yield occurred in the control tree although no signs of wintering were observed. This drop in yield cannot be accounted for as it was not shown by adjoining trees of clone Tjir 1 outside the experiment. The values for total solids at the various sampling points of the control tree increased markedly and at the low yield of 34 millilitres of latex per tapping, dilution reaction was observed only at the sampling point situated two feet below the tapping cut.

The yield of the treated tree reached a value slightly above the pre-treatment level and the values for total solids at positions of five feet above the tapping cut, on the stock stem and on the main lateral root recovered to their pre-treatment level.

The values at the +2 feet, –2 feet and –3 feet positions remained slightly below the pre-treatment level.

An increase in the spread of the dilution effect both above and below the tapping cut after treatment with yield stimulant has been demonstrated. The full data show a more rapid spread in a downward direction, although during the peak yield period the extent of the dilution reaction was found to be approximately the same at positions of five feet above the tapping cut and on a main lateral root three feet from the tap root.

It is noted that during the period of increased yields caused by treatment with yield stimulant the 'reconcentration' of latex in the latex vessels at positions near the tapping cut follows the pattern postulated by Frey Wyssling (1932) but the pre-treatment values are not reached and the latex remains more diluted. When the main effect of the yield stimulant had worn off both the yield and the values for total solids returned to nearly their pre-treatment level.

TABLE IV: PERCENTAGE OF TOTAL SOLIDS OF LATEX

Each figure is the mean of

	Time of sampling
Before application of yield stimulant	
Period I	
Mean yield of 8 tappings: *treated* *control* *75 mls* *86 mls*	*Before tapping* *2 hours after* *4 hours after*
After application of yield stimulant	
Period II	
Mean yield of 8 tappings: *treated* *control* *196 mls* *119 mls*	*Before tapping* *2 hours after* *4 hours after*
Period III	
Mean yield of 8 tappings: *treated* *control* *285 mls* *113 mls*	*Before tapping* *2 hours after* *4 hours after*
Period IV	
Mean yield of 8 tappings: *treated* *control* *113 mls* *34 mls*	*Before tapping* *2 hours after* *4 hours after*

T = treated with yield stimulant

The results confirm the suggestion that the latex draining area of the bark is increased by treatment with a yield stimulant and that this increase may account for the low incidence of brown bast in areas treated with yield stimulants.

The drop in the values of total solids of the latex in situ two hours after tapping is considerably increased by treatment with yield stimulant, as shown in TABLE V.

TABLE V: DILUTION REACTION AT TWO FEET BELOW THE TAPPING CUT

Percentage of total solids	*Before tapping*	*2 hours after tapping*	*Difference*
Period I before treatment with yield stimulant	51.9	45.3	6.6
Period II after treatment with yield stimulant	46.8	34.6	12.2
Period III after treatment with yield stimulant	46.1	31.3	14.8
Period IV after treatment with yield stimulant	48.9	38.9	10.0

IN SITU AT DIFFERENT PLACES IN THE TREE

eight successive samplings

+5 ft		*+2 ft*		*−2 ft*		*−3 ft*		*Stock*		*Root*	
T	*C*	*T*	*C*	*T*	*C*	*T*	*C*	*T*	*C*	*T*	*C*
48.5	45.9	49.2	48.0	51.9	50.9	49.8	49.9	46.4	50.0	42.4	51.5
46.9	44.3	45.9	47.4	45.3	47.0	43.3	45.1	40.8	43.8	43.5	52.2
47.6	46.1	47.6	47.4	48.3	48.2	44.5	47.1	41.9	47.1	42.2	51.2
44.5	45.6	43.9	49.7	46.8	52.4	46.5	53.7	44.5	51.3	*37.5*	53.3
39.6	44.9	39.7	43.2	34.6	45.4	35.8	44.2	36.0	43.6	*33.8*	52.5
40.9	44.6	39.8	46.2	38.2	47.7	37.6	46.9	37.6	45.8	*34.1*	51.9
41.5	47.9	39.7	48.4	46.1	53.5	46.3	53.0	41.8	51.6	*36.7*	53.3
37.6	46.3	34.9	45.6	31.3	45.4	33.6	44.3	34.2	46.3	*33.6*	51.8
34.9	44.7	33.2	46.4	35.5	48.7	36.5	47.1	34.3	46.2	*32.2*	51.6
49.2	57.3	48.3	56.9	48.9	58.8	47.8	54.9	45.5	56.4	43.9	55.5
48.4	57.8	45.1	57.0	38.9	55.8	38.2	55.4	39.8	55.8	42.8	54.3
48.2	58.0	45.6	58.7	41.4	56.5	39.8	54.9	41.4	55.6	41.5	55.0

C = control

Frey Wyssling's suggestion that damage to the parenchyma cells near the tapping cut, where symptoms of brown bast first appear, 'as a result of the considerable oscillation of the suction power to which they are exposed every time the tubes are opened . . . .' is not supported by the results of this experiment in which large increases in dilution of the latex in situ near the tapping cut have been recorded after treatment with a yield stimulant, and by the fact that no increased brown bast incidence has been observed after treatment with yield stimulant on a commercial scale.

CHANGES IN BARK ANATOMY

It is known that application of 2,4-D and 2,4,5-T in herbicidal concentrations to plants results in induced meristematic activity in the phloem region (TUKEY 1945), (BEAL 1946), (SWANSON 1946), (EAMES 1949).

Trees treated with a yield stimulant on a three inch wide strip of lightly scraped bark below the tapping cut at intervals of six months show an increase in bark thickness above the cut (Baptist and de Jonge 1955).

If this increase takes place through activation of the cambium a measure of the effect would be provided by the proportion of the number of latex vessels in the renewing bark to the number of latex vessels in the virgin bark immediately above the tapping panel.

Microscopical examination of sections of 20 months old renewed bark of trees treated with a 1% 2,4,5-T yield stimulant and of control trees has revealed no significant differences, the percentage being 46.7 and 44.5 per cent respectively, and showed clearly that the increased thickness was located in the non latex bearing outer portion of the bark. The renewed bark has a healthy appearance and does not contain an excessive amount of stone cells in the outer layers. Application of 2,4-D or 2,4,5-T to the bark does not result in an increase of latex vessel rows in the renewing bark, but only in the formation of masses of undifferentiated tissue.

A similar but more exaggerated picture is obtained when the yield stimulant is applied above the tapping cut (Baptist and de Jonge 1955). Under the conditions of our experiments the thickness of one year old renewed bark on the treated trees was nearly three times that on control trees but all of the extra thickness is made up of undifferentiated parenchymatous tissue which in its outer layers has become hardened by excessive stone cell formation. A soft spongy layer of parenchymatous tissue, containing fragments of latex vessels pushed outwards by the meristematic activity induced by the yield stimulant, lies between this hard outer layer and the inner layers which show the normal features of the soft bast.

Application of yield stimulant above the cut results in irregular bark renewal. Tapping wounds become exaggerated and the outer layers of the bark were found to flake off readily when bark samples were collected for anatomical examination. This method of applying yield stimulant cannot therefore be recommended for use on trees in which the treated bark is to be tapped after renewal until the long term effects on bark anatomy and productivity have been ascertained.

Bark damage after application of yield stimulants has been reported from several plantations. In nearly all cases brought to our notice, damage had been caused by excessive application to the scraped bark of the mixture which runs down the bark and accumulates on the unscraped bark below the site of application.

This may result in a disruption of the normal anatomical structure of the bark by meristematic activity induced in parenchyma tissue of the soft bast pushing the latex vessels outwards and in extreme cases, tearing them apart. The external appearance of the bark reveals swellings and cracks.

GROWTH

All our experiments to date have been carried out on rubber trees exceeding 20 years of age with small yearly girth incre-

ments and on which a retarding effect on growth is not easily established. It is an established fact that tapping retards growth, the heavier the tapping intensity the greater the retardation in growth, and that a competition exists between the secondary function of rubber formation and the primary growth of the tree.

It would not, therefore, be unreasonable to expect that the highly increased yields brought about by yield stimulants would have a retarding effect on growth, particularly of young trees. There is some evidence from our experiments of a disappearance of starch in bark below the tapping cut of trees treated with yield stimulant but it is not known to what extent the reserve carbohydrate not used up in normal tapping is mobilised as a result of treatment with yield stimulant. The utilisation of this reserve carbohydrate while it lasts may postpone the retardation of growth but the too frequent use of yield stimulants on young budded and seedling trees cannot be recommended until their effects on growth and future performance have been ascertained from reliable experiments.

YIELD TREND

A surprisingly early response to yield stimulant applied below the tapping cut has been observed in nearly all our experiments. The peak yield is generally reached within a fortnight after treatment and this is followed by a gradual decline, the effect wearing off approximately three months later, frequently followed by a second shorter period of slightly increased yields.

The rate and duration of latex flow on tapping trees treated with yield stimulant and untreated trees have been measured and the results of one typical example during the peak yield period are presented in *Figure 4*.

The latex yield was measured at intervals of 10 minutes from the opening of the tapping cut until the cessation of flow.

Curve (*A*) shows the yield trend of a tree treated with yield stimulant and curve (*B*) the yield trend of an untreated tree on the same day. It is seen that two hours after tapping, the bulk of the increased yield due to yield stimulant would have been collected. This is possible because of the greater rate of latex flow of the treated trees. Postponing the time of latex collection by one hour would, in most cases, allow for the collection as latex of the excess yield produced by the longer duration of flow. The few trees which continue to drip latex at a slow rate after this extension of time would not justify a longer postponement of latex collection (Botanical Division 1953).

PROPERTIES OF LATEX

DRY RUBBER CONTENT

Treatment with yield stimulant causes a gradual fall in the dry rubber content of the latex which reaches its lowest value in the second month and then recovers slowly to nearly its original level.

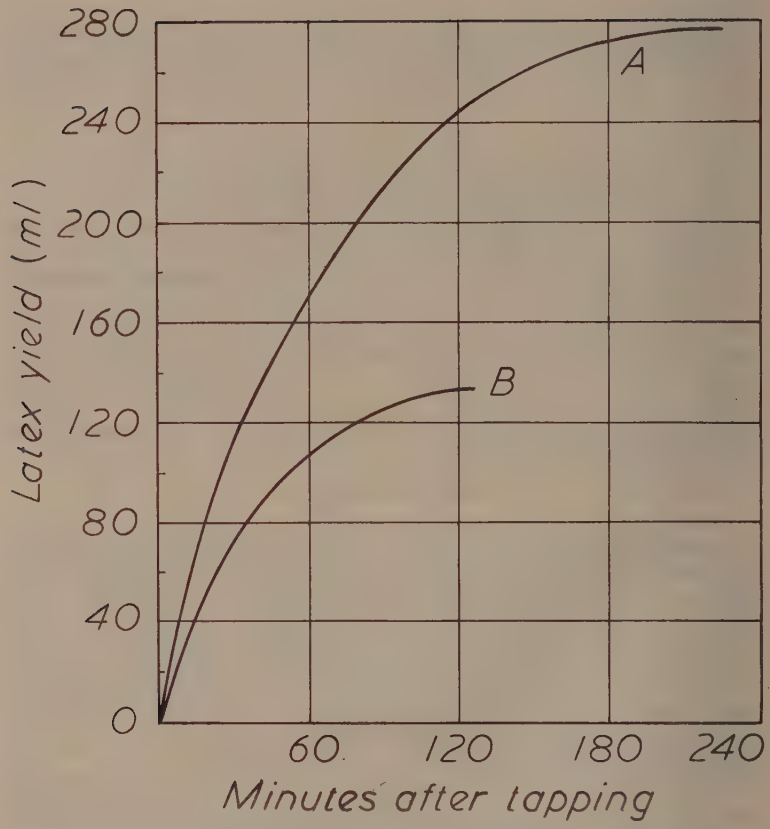


Figure 4. Rate and duration of latex flow on tapping. A—treated trees. B—control trees.

Determination of dry rubber content of the latex in our long term experiment (Baptist and de Jonge 1955) commenced at the time of the second treatment with yield stimulant. The DRC values shown in TABLE VI represent the mean of 54 trees.

The fall in DRC caused by treatment with yield stimulant would not be expected to be large enough, at least in the 20 years old trees used in this experiment, to have any adverse effect on the processing of the latex.

Changes in the total solids content of the latex over shorter periods following treatment of a budded tree of clone Tjir 1 with yield stimulant are shown in TABLE VII. Each figure is the mean of six successive tappings.

The decrease in percentage total solids and consequently the lower viscosity of the latex may increase the rate of flow of latex on tapping. The observation does not however explain the result

TABLE VI: DRC OF LATEX FROM TREATED AND CONTROL TREES

Interval after treatment	*Treated trees*	*Control trees*	*Treatment as percentage of control*
1st month after second treatment	42.0	44.5	94
2nd month after second treatment	38.0	42.5	89
3rd month after second treatment	40.0	44.0	91
4th month after second treatment	40.8	43.0	95
5th month after second treatment	40.8	42.3	96
6th month after second treatment	39.3	41.0	96
7th month after second treatment	40.8	41.8	98
1st month after third treatment	39.0	40.8	96
2nd month after third treatment	36.0	41.0	88
3rd month after third treatment	41.0	43.0	95
4th month after third treatment	42.8	44.0	97
5th month after third treatment	42.5	44.0	97
6th month after third treatment	43.0	44.3	97
1st month after fourth treatment	42.0	44.0	95
2nd month after fourth treatment	40.3	44.5	91
3rd month after fourth treatment	39.0	42.5	92
4th month after fourth treatment	40.0	41.5	96
5th month after fourth treatment	39.5	41.0	96
6th month after fourth treatment	41.0	41.3	99

of our other experiments, in which the dry rubber content reached its lowest values in the second month whereas the highest yields were recorded in the first month.

COPPER CONTENT

When injection of copper sulphate into the stem of rubber trees was found to increase the latex yield (Compagnon and Tixier 1950) an investigation of the copper content of the latex before and after injection was carried out with the main object of ascertaining the limits of the increase in copper content of the latex.

With this end in view an experiment was carried out in collaboration with our Chemical Division and showed inter alia that the increase in yield is caused by the copper ion and that the

TABLE VII: YIELDS AND TOTAL SOLIDS CONTENT OF LATEX

Before and after treatment	*Yield in mls*	*Yield as percentage of pre-treatment yield*	*Percentage total solids*	*Total solids as percentage of pre-treatment value*
Before treatment	75.1	100	43.5	100
After treatment				
First 6 tapping days	100.7	134	44.0	101
Second 6 tapping days	171.0	228	40.5	93
Third 6 tapping days	196.4	262	38.5	89
Fourth 6 tapping days	232.0	309	36.9	85
Fifth 6 tapping days	153.2	204	36.7	84
Sixth 6 tapping days	135.0	180	39.3	90
Seventh 6 tapping days	71.2	95	40.8	94
Eighth 6 tapping days	111.8	149	40.8	94

injection of 10 grams of copper sulphate into the main stem does not cause an appreciable increase in the copper content of the latex.

Further, to verify the claim that copper sulphate injection is a cure for brown bast (Tixier 1951), an experiment was carried out in which thirty trees which had been rested because of brown bast were injected with copper sulphate and the same number of trees were treated with the proprietary yield stimulant, 'Stimulex', which was found to contain the insignicant amount of 3.6 parts per million of copper.

The copper sulphate was applied in powder form to two auger holes bored into the tree, one at each end of the half spiral tapping cut, at the rate of 5 grams per hole and the 'Stimulex' was applied to a three inch strip of lightly scraped bark below the tapping cut.

Both treatments increased the yield of all trees and the increase in yield level has been maintained todate by repeated applications of the treatment.

A summary of the data of yield, dry rubber content of latex and copper content of the total solids of the latex is given in TABLE VIII. The yields are expressed as grams of air dried rubber per tree per tapping.

The pretreatment yields cover a period of only fourteen days as it was feared that the trees might go dry before the treatments were applied. The increase in copper content of the latex after the application of the treatments is noteworthy and the possibility that this was caused by contamination with copper sulphate is ruled out by the fact that an increase in the copper content of

the latex of the same order is found after treatment with 'Stimulex'.

The copper content values after the third application of treatments are especially interesting as they show a clear increase during the peak yield period in the first month after the application of the treatments and a decrease when the effect of treatment on yield wears off. There is, moreover, a sharp fall in copper content when tapping is on a new cut opened on the opposite side of the tree. But a steep increase corresponds with the peak yield period following the application of treatments to the new tapping panel.

Determination of copper content was unfortunately discontinued in the early part of the fourth period and yield recording ceased at the end of the six months of this period.

The trend of the copper content would suggest some relation with secondary rubber formation and possibly an increased activity of copper containing enzymes concerned in this process. This forms the subject of further investigation now in progress.

PROPERTIES OF LATEX CONCENTRATES AND DRY RUBBER

Our findings of an increase in copper content of the latex after treatment with yield stimulant led to a large scale experiment to investigate the properties of the latex concentrate and dry rubber obtained from both treated and untreated trees.

The experiment was set up on low yielding 24 years old seedling trees (Field 23 Rubber Research Institute Experiment Station) in collaboration with our Chemical Division in which all tests on latex and rubber have been carried out. The experimental area was divided into eight tapping tasks, four of which were treated with yield stimulant (2,4,5-T as a one per cent acid equivalent solution in palm oil thickened with Vacuum Product 2295C) below the tapping cut and four tasks served as control. The yields were recorded for two months before treatment. Tapping was alternate daily on a half spiral cut. The results are summarised in TABLE IX.

Prior to the application of yield stimulant four latex collections were made from both treated and control tasks and the latex was made into concentrate, smoked sheet, air dried sheet and crepe. Samples of latex total solids were also prepared.

One week after treatment with yield stimulant latex concentrate, latex total solids and smoked sheet were prepared from the latex of treated and control tasks. After a lapse of one month latex concentrate, latex total solids, smoked sheet, air dried sheet and crepe were prepared from the latex crop obtained on separate days.

Two months and three months after the date of application of yield stimulant latex concentrate, latex total solids, and smoked sheet were prepared. The latex total solids were examined for copper content.

TABLE VIII: EFFECT OF YIELD STIMULANTS ON

Before and after treatment	*Copper sulphate*		
	Yield	*DRC*	*Copper content of total solids*
Before treatment	48.9	41.0	0.00029
First treatment			
First month	70.5	34.5	0.00076
Second month	53.3	30.0	0.00098
Third month	50.7	31.0	0.00103
Second treatment			
First month	54.2	32.9	0.00107
Second month	54.7	33.5	0.00116
Third month	50.6	34.9	0.00104
Fourth month	48.3	36.0	0.00110
Fifth month	43.9	37.0	0.00093
Sixth month	54.0	35.0	0.00104
Third treatment			
First month	64.3	33.0	0.00142
Second month	46.4	32.0	0.00120
Third month	50.2	32.0	0.00123
Fourth month	27.6*	35.0*	0.00111*
Fifth month	26.7†	41.0†	0.00061†
Fourth treatment			
First month	58.9	—	—
Second month	41.4	35.0	0.00107
Third month	42.9	—	—
Fourth month	36.4	—	—
Fifth month	32.8	—	—
Sixth month	34.4	—	—

† *Cuts changed over to opposite side of tree*

The Williams plasticity of crepes before and after ageing at elevated temperature and in sunlight was measured. The airdried sheet were examined for copper content and the properties of an A.C.S.I. vulcanisate were determined before and after ageing. The dry rubber content, total solids content, ammonia, volatile fatty acid No., KOH No., mechanical stability and copper content of the latex concentrates were measured. A tyre tread mix was made from the smoked sheet samples and the effect of ageing upon the physical properties of the vulcanisate was evaluated. The copper content of the smoked sheet was also checked. Full results of these tests are deposited in the research archives of the Rubber Research Institute of Malaya (RRIM Document VI).

The following conclusions have been made:

1 Treatment with a yield stimulant, which itself contains only the insignificant amount of 1.2 ppm of copper, resulted in an increase of the copper content of the field latex, the maximum increase observed being from 4 to 7 ppm. The copper content of latex concentrate and smoked sheet prepared from latex of treated trees

Stimulex			*Before and after treatment*
Yield	*DRC*	*Copper content of total solids*	
27.9	42.5	0.00020	*Before treatment*
			First treatment
58.5	35.0	0.00058	*First month*
42.1	30.5	0.00087	*Second month*
37.8	30.5	0.00089	*Third month*
			Second treatment
50.3	31.5	0.00090	*First month*
47.4	32.0	0.00108	*Second month*
36.9	33.0	0.00092	*Third month*
36.1	38.0	0.00097	*Fourth month*
34.0	35.0	0.00079	*Fifth month*
39.9	36.0	0.00094	*Sixth month*
			Third treatment
41.4	34.0	0.00133	*First month*
29.5	33.0	0.00112	*Second month*
33.4	34.0	0.00105	*Third month*
18.0*	35.0*	0.00097*	*Fourth month*
19.4†	41.0†	0.00044†	*Fifth month*
			Fourth treatment
38.7	—	—	*First month*
31.8	37.0	0.00077	*Second month*
29.0	—	—	*Third month*
26.2	—	—	*Fourth month*
25.1	—	—	*Fifth month*
24.2	—	—	*Sixth month*

* *Cuts tapped at reduced length on reaching ground level*

was, however, very little higher than that from untreated trees, an increase was observed in one case only, the change being from 2 to 3 ppm.

The extra copper in the field latex is presumably lost in the operation of centrifuging or coagulation.

2 The properties of latex concentrate were unaffected by stimulant treatment.

3 The ageing properties of raw crepe prepared from latex of stimulated trees did not show significant evidence of deterioration.

4 The colour of air dried sheet prepared from latex of treated trees was unaltered and the physical properties of an A.C.S.1 vulcanisate before and after ageing remained unaffected.

5 The technical properties of a tyre tread mix made from smoked sheet prepared from the latex of control and of treated trees up to three months from the time of treatment were identical. After ageing the vulcanisates

TABLE IX: MEAN MONTHLY YIELDS EXPRESSED AS LB PER TASK PER TAPPING AND AS A PERCENTAGE OF THE CONTROL

Yields before and after treatment	*Treated tasks*		*Control tasks*
	Yield	*% control*	*Yield*
Pretreatment yields (Nov and Dec '53)	7.2	122	5.9
First month after treatment	10.4	242	4.3
Second month after treatment	8.9	241	3.7*
Third month after treatment	6.6	169	3.9*
Fourth month after treatment	6.4	149	4.3
Fifth month after treatment	7.1	131	5.4
Sixth month after treatment	7.7	124	6.2

* *Wintering months*

for 14 days at 70°C, the change in physical properties was the same for both groups of sheet.

This abstract from a report issued by our Chemical Division shows that treatment with a yield stimulant has no appreciable effect on the properties of either the latex concentrate or the dry rubber, notwithstanding the fact that a slight rise in copper content of the field latex was noted, as much of the excess copper remains in the skim or serum.

The use of a yield stimulating mixture containing copper sulphate, for application to bark below the tapping cut, has been advocated in Indonesia (WIERSUM 1954) and the publication has been reproduced in the July 1954 issue of *The Planter*, the official journal of the Incorporated Society of Planters in Malaya.

The American Society for Testing Materials has specified that the copper content of latex concentrates should not exceed 10 parts per million and the Rubber Manufacturers Association of New York has laid down the regulation that no RMA grade rubber may contain more than 8 parts per million of copper because of the catalytic effect which copper exerts on the rate of oxidation of rubber.

Rubbers which contain copper appreciably in excess of the specified limits soften rapidly and become sticky and this process may persist after the raw rubbers have been converted into manufactured articles.

As eight parts per million of copper in the finished rubber is equivalent to an addition of only two ounces of copper sulphate to 1,000 gallons of field latex we would issue a strong warning against the use of copper containing yield stimulants, owing to the great risk of copper contamination of the latex in normal tapping.

SUMMARY

The response of the rubber tree to yield stimulants is shown to be influenced by the condition of the bark, the type of planting material, the tapping system, the composition and method of application of the mixture.

An extension of the area of rubber extraction in the bark of trees in normal tapping as a result of treatment with yield stimulant has been demonstrated experimentally and is thought to account for the increased yields obtained and for the low incidence of brown bast after repeated treatments.

The increase in bark thickness observed is caused by induced meristematic activity in the cortical and phloem regions, resulting in prolific development of undifferentiated parenchyma tissue, and not by activation of the vascular cambium.

The rate and duration of latex flow are increased after treatment with a yield stimulant and there is a slight decrease in the dry rubber content of the latex which usually reaches its lowest value in the second month following treatment.

The copper content of the latex shows a small increase which, however, would appear to have no appreciable effect on the properties of either the rubber or the latex concentrate.

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Rubber Research Institute of Malaya
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